Final report

OWMC
Ontario
Waste Management
Corporation

A provincial crown corporation

Gartner
Lee
Associates
Limited

SITE ASSESSMENT - PHASE 4B: GEOLOGY, HYDROGEOLOGY, AND GEOTECHNICS - POTENTIAL IMPACTS ON GROUND WATER FROM THE CENTRAL OPERATING AREA

Prepared for
The Ontario Waste Management Corporation

Submitted By

Gartner Lee Limited

November, 1987

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November 24, 1987

GLL 87571

Mr. J.G. Micak
Manager, Environmental Projects
Ontario Waste Management Corporation
2 Bloor Street West
11th Floor
Toronto, Ontario
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Attention: Mr. D.F. Chollak,
Environmental Planner

Dear Sirs:

Re: Site Assessment Phase 4B: Geology, Hydrogeology and Geotechnics - Potential Impacts on Ground Water from the Central Operating Area

We are pleased to provide you with our above noted report.

This report is one of six Phase 4B companion reports describing; baseline conditions, hydrogeologic inputs to landfill design, geotechnical inputs to facilities design, potential impacts on ground water from the Central Operating Area, potential impacts of the landfill on ground water and ground water management strategies.

We thank you for this opportunity to be of service. Should you have any questions, please do not hesitate to call.

Yours very truly,

GARTNER LEE LIMITED

for E.G. Anderson, P.Eng.,
Consulting Hydrogeologist
Project Director

G.W. Reynolds, M.Sc.,
Senior Hydrogeologist
Project Manager

Encl.
GWR:emh

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1.0 INTRODUCTION

1.1 PURPOSE

This report documents a portion of the geoscience studies (which incorporate geology, hydrogeology, and geotechnics) carried out as part of Phase 4B of the Ontario Waste Management Corporation's (OWMC) Facilities Development Process. Phase 4B involves detailed assessments of the Preferred Site and surrounding area based on several disciplines, including the geosciences. The Preferred Site and immediate vicinity are illustrated in Figure 1-1.

The specific objectives of Phase 4B are to:

1. Define the existing environmental conditions (baseline) of the Preferred Site,

2. Predict and assess potential risks and impacts that may be associated with the proposed facility design and operations,

3. Identify and develop appropriate mitigative measures to minimize the potential risks and impacts,

4. Interpret residual risks and impacts after mitigation.

5. Identify and develop monitoring programs that will be implemented to assess the effectiveness of the design and operations in minimizing risks and impacts,

6. Identify and develop contingencies that could be implemented if needed to minimize risks and impacts, and

7. Prepare documentation to meet the requirements of Ontario's Environmental Assessment Act.

Township of West Lincoln, Regional Municipality of Niagara. Local Detail.

OWMC, 1985.

OWMC Ontario Waste Management Corporation

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Preferred Site
Figure 1.1

Figure 1-2 illustrates how Phase 4B relates to the other Phases of the OWMC Site Assessment and Facilities Development Process. For the geosciences, Gartner Lee Limited's (GLL) Phase 4B studies have focused on:

1. Establishing baseline conditions for the Preferred Site (GLL 1987a),

2. Providing input to OWMC's engineering consultants for conceptual facilities design (GLL 1987b; 1987c),

3. Assessing potential ground water impacts from the Central Operating Area (COA) (this report),

4. Assessing, mitigating and comparing various engineered landfill design concepts as input to OWMC's selection of the shallow entombed landfill (GLL 1987b),

5. Assessing potential ground water impacts from the shallow entombed landfill (GLL 1987d), and

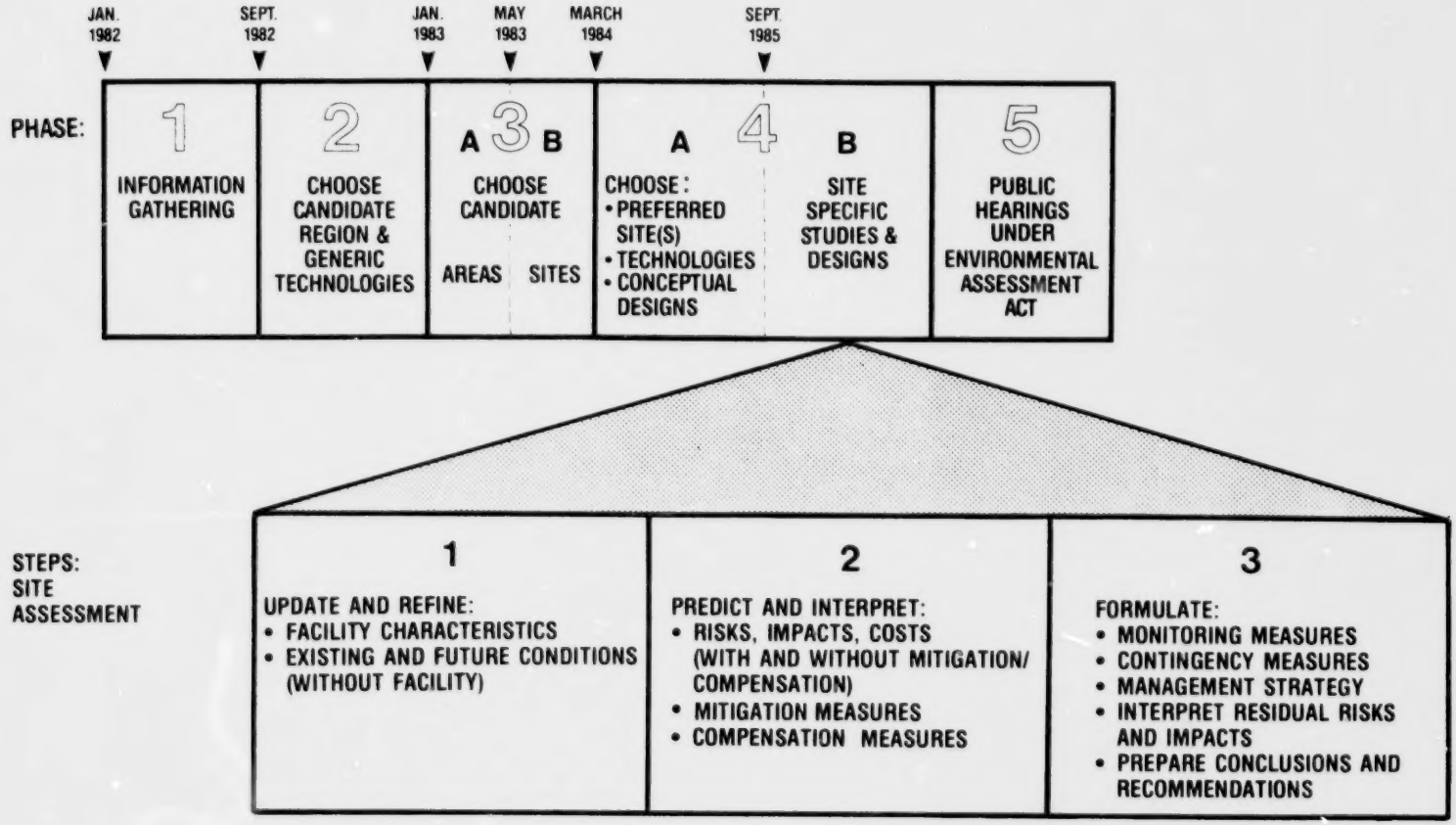
6. Developing an overall ground water management plan through monitoring, decommissioning and remedial strategies (GLL 1987e).

1.2 SCOPE

As noted above, this report provides an assessment of the ground water impacts that may occur as a result of the design and operation of the Central Operating Area (COA) of the OWMC facility. Figure 1-3 illustrates how this report fits into GLL's Phase 4B studies. The scope of this report is also shown in Figure 1-3.

This report relates to the Phase 4B ground water factor indicators. They are:

1. Impact of the Central Operating Area on ground water flow, (particularly as it relates to the availability of ground water for domestic, industrial and agricultural uses), and
2. Impact of the Central Operating Area on ground water quality.



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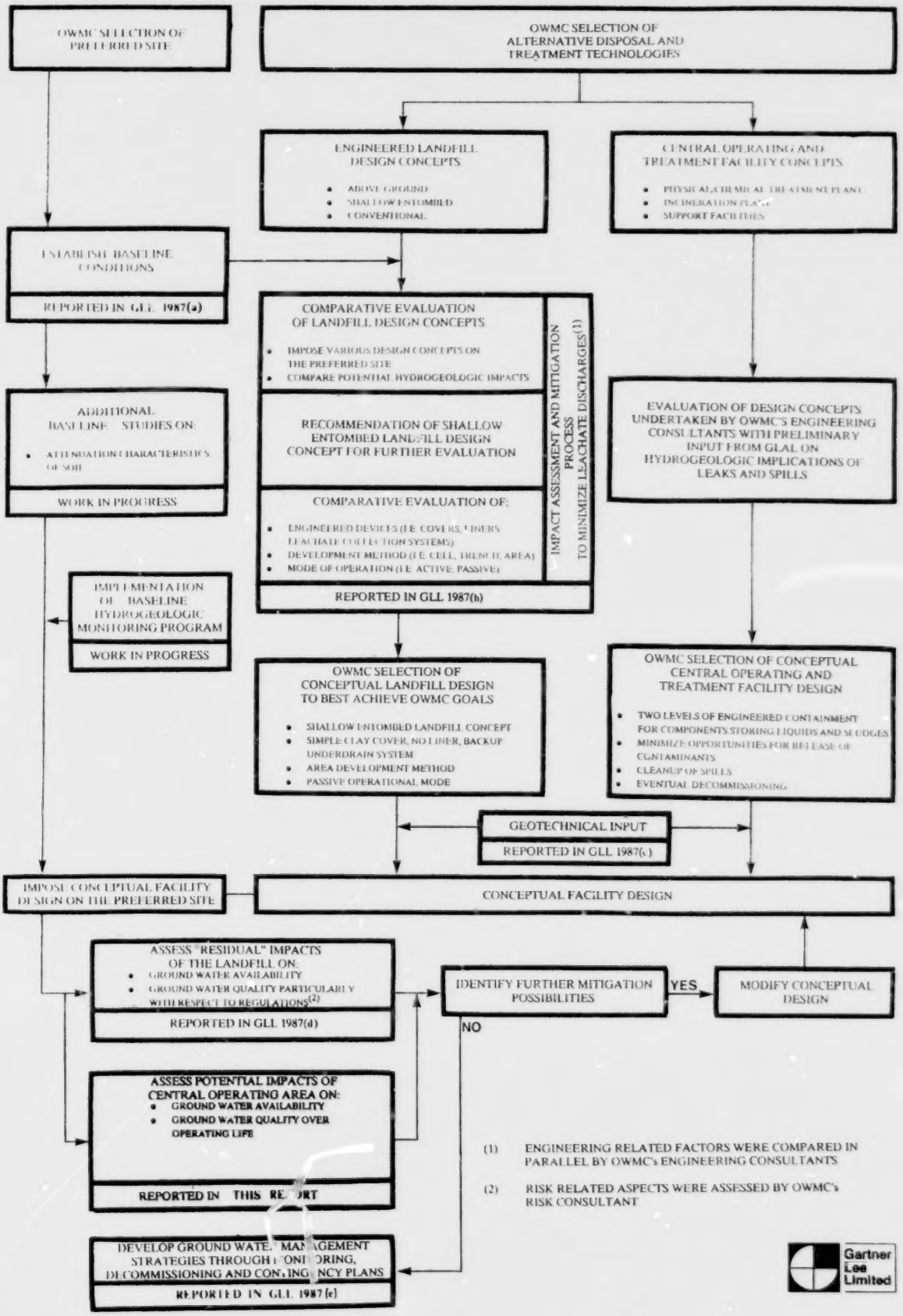
FACILITIES DEVELOPMENT PROCESS

Figure 1.2

FIGURE 1-3
PHASE 4B: IMPACT ASSESSMENT APPROACH: Geoscience


OWMC SELECTION OF PREFERRED SITE
OWMC SELECTION OF ALTERNATIVE DISPOSAL AND TREATMENT TECHNOLOGIES
ENGINEERED LANDFILL DESIGN CONCEPTS
ABOVE GROUND
SHALLOW ENTOMBED
CONVENTIONAL
CENTRAL OPERATING AND TREATMENT FACILITY CONCEPTS
PHYSICAL/CHEMICAL TREATMENT PLANT
INCINERATION PLANT
SUPPORT FACILITIES
ESTABLISH BASELINE CONDITIONS
REPORTED IN GLL 1987(a)
COMPARATIVE EVALUATION OF LANDFILL DESIGN CONCEPTS
IMPOSE VARIOUS DESIGN CONCEPTS ON THE PREFERRED SITE
COMPARE POTENTIAL HYDROGEOLOGIC IMPACTS
RECOMMENDATION OF SHALLOW ENTOMBED LANDFILL DESIGN CONCEPT FOR FURTHER EVALUATION
COMPARATIVE EVALUATION OF:
ENGINEERED DEVICES (I.E. COVERS, LINERS LEACHATE COLLECTION SYSTEMS)
DEVELOPMENT METHOD (I.E. CELL, TRENCH, AREA)
MODE OF OPERATION (I.E. ACTIVE, PASSIVE)
REPORTED IN GLL 1987(b)
IMPACT ASSESSMENT AND MITIGATION PROCESS TO MINIMIZE LEACHATE DISCHARGES(1)
EVALUATION OF DESIGN CONCEPTS UNDERTAKEN BY OWMC'S ENGINEERING CONSULTANTS WITH PRELIMINARY INPUT FROM GLAL ON HYDROGEOLOGIC IMPLICATIONS OF LEAKS AND SPILLS
ADDITIONAL BASELINE STUDIES ON:
ATTENUATION CHARACTERISTICS OF SOIL
WORK IN PROGRESS
IMPLEMENTATION OF BASELINE HYDROGEOLOGIC MONITORING PROGRAM
WORK IN PROGRESS
OWMC SELECTION OF CONCEPTUAL LANDFILL DESIGN TO BEST ACHIEVE OWMC GOALS
SHALLOW ENTOMBED LANDFILL CONCEPT
SIMPLE CLAY COVER, NO LINER, BACKUP UNDERDRAIN SYSTEM
AREA DEVELOPMENT METHOD
PASSIVE OPERATIONAL MODE
OWMC SELECTION OF CONCEPTUAL CENTRAL OPERATING AND TREATMENT FACILITY DESIGN
TWO LEVELS OF ENGINEERED CONTAINMENT FOR COMPONENTS STORING LIQUIDS AND SLUDGES
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EVENTUAL DECOMMISSIONING
GEOTECHNICAL INPUT
REPORTED IN GLL 1987(c)
IMPOSE CONCEPTUAL FACILITY DESIGN ON THE PREFERRED SITE
CONCEPTUAL FACILITY DESIGN
ASSESS "RESIDUAL" IMPACTS OF THE LANDFILL ON:
GROUND WATER AVAILABILITY
GROUND WATER QUALITY PARTICULARLY WITH RESPECT TO REGULATIONS(2)
REPORTED IN GLL 1987(d)
IDENTIFY FURTHER MITIGATION POSSIBILITIES
YES
MODIFY CONCEPTUAL DESIGN
NO
ASSESS POTENTIAL IMPACTS OF CENTRAL OPERATING AREA ON:
GROUND WATER AVAILABILITY
GROUND WATER QUALITY OVER OPERATING LIFE
REPORTED IN THIS REPORT
DEVELOP GROUND WATER MANAGEMENT STRATEGIES THROUGH MONITORING, DECOMMISSIONING AND CONTINGENCY PLANS
REPORTED IN GLL 1987(e)
(1) ENGINEERING RELATED FACTORS WERE COMPARED IN PARALLEL BY OWMC's ENGINEERING CONSULTANTS
(2) RISK RELATED ASPECTS WERE ASSESSED BY OWMC's RISK CONSULTANT
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Chapters 2.0 and 3.0 discuss the results of the impact assessment on ground water flow and ground water quality, respectively.

The main components of the COA are the incineration plant, the physical/chemical treatment plant, the solidification plant, and the associated transfer, storage, and administrative facilities (Monenco Ltd. 1987). In most cases, the conceptual design of the facilities provides double levels of containment against leakage and spills. These can be considered as basic mitigation for readily anticipated ground water impacts.

Chapter 4.0 provides the conclusions and recommendations of the report.

1.3 ASSUMPTIONS AND BACKGROUND DATA

1.3.1 Geoscience

The baseline geologic, hydrogeologic, and geotechnical conditions at the Preferred Site are described in the report entitled "Site Assessment Phase 4B: Geology, Hydrogeology and Geotechnics - Baseline Conditions" (GLL 1987a). The site characteristics detailed in that report are the basis for the impact analyses presented in this report.

1.3.2 Facilities Design

OWMC's engineering consultants have established the conceptual design for the facilities at the Preferred Site. The conceptual design data have been assumed in the impact analyses presented in this report. The most comprehensive summary of the conceptual design is contained in the report entitled "Design and Operations" (Monenco Ltd. 1987). A series of earlier reports entitled "OWMC Treatment Facility Process Area Reports" also provided detailed technical information regarding the conceptual design. Pertinent Process Area Reports (PARs) are listed below for reference:

- General Facilities PAR (Monenco Ltd. 1986a),
- Incineration PAR (Monenco Ltd. 1986b),
- Physical/Chemical Treatment PAR (Monenco Ltd. 1986c),

- Solidification PAR (Monenco Ltd. 1986d),
- Engineered Landfill PAR (Monenco Ltd. 1986e), and
- Facility Description PAR (Monenco Ltd. 1986f).

The layout of the site is illustrated in Figure 1-4 for reference. This report deals only with the impacts associated with the facilities contained in the COA. Potential impacts from the landfill are discussed in a companion report (GLL 1987d). Note that the COA is surrounded by landfilling areas and is a minimum distance of 175 metres from the nearest site boundary. It is also important to note that the OWMC facilities will not use ground water as a source of water supply and thus will not cause any well interference problems with local water wells.

One of the most important assumptions contained in these reports for the purposes of impact assessment is that the COA facilities have a finite operating life. As such, the COA facilities will be decommissioned after their useful life and the site left in an environmentally safe condition consistent with its surroundings and proposed future use. The operating life is assumed to be 50 years from the start-up date (Monenco 1986a).

A second important conceptual design feature is that double levels of engineered containment are provided for components of the COA facilities. These greatly reduce the risk of ground water contamination. Appendix A summarizes the important engineered containment systems and operational considerations that relate to the hydrogeologic analysis presented in this report. It is important to note the fundamental difference between the landfill and the treatment plant facilities with regard to the life of engineered containment systems. While the landfill engineered devices are assumed to fail within the effective lifetime of the landfill (hundreds of years, GLL 1987b), the engineered containment systems in the treatment facility are assumed to operate efficiently throughout the entire 50 year period prior to decommissioning.

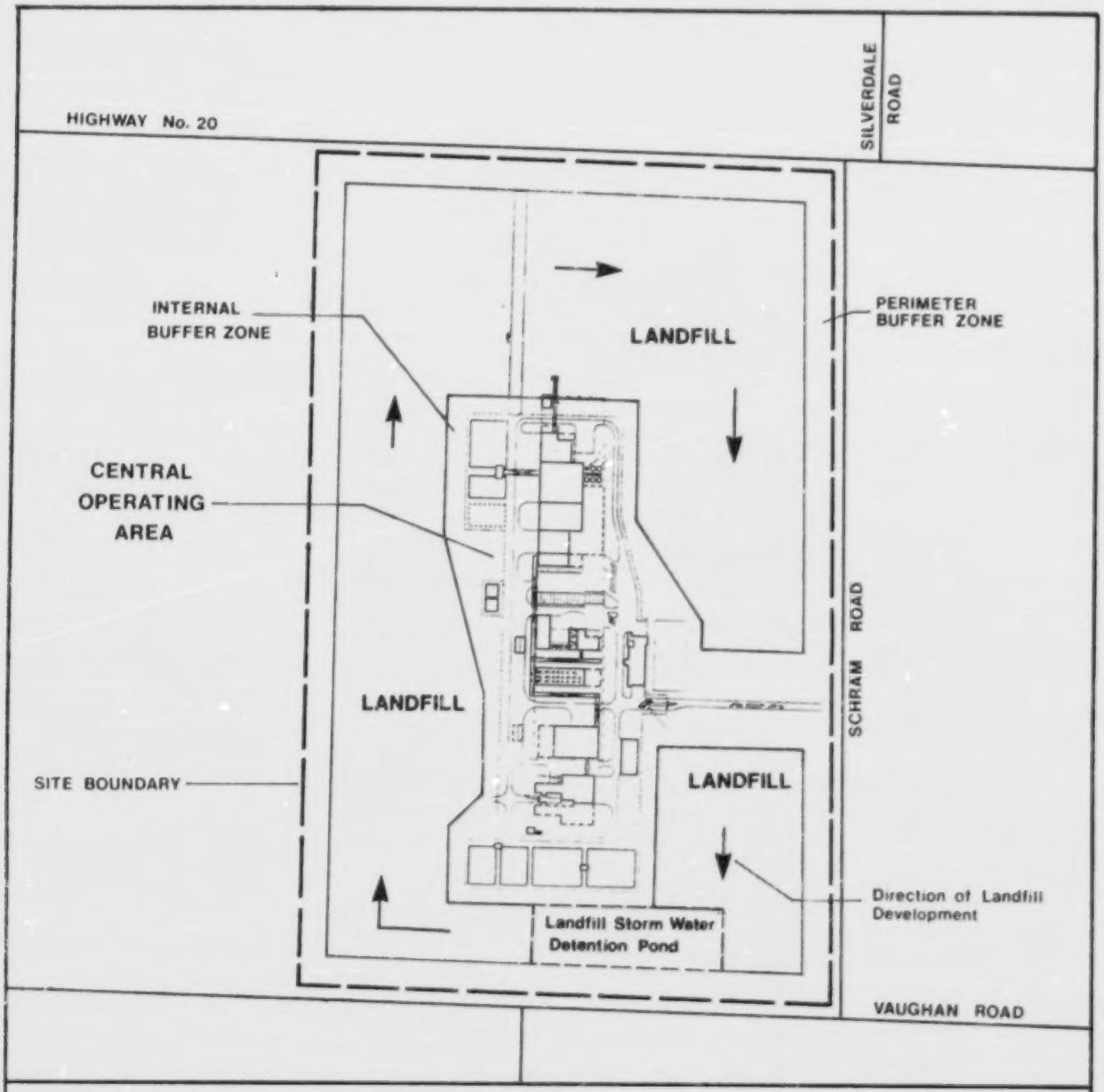


Figure 1·4
PLAN VIEW OF PROPOSED OWMC FACILITY

0 250 500
METRES

NOTE: (1) Details on the Central Operating Area are Provided in the Design and Operations report (Monenco, 1987).
(2) Landfill Storm Water Detention Pond Location Approximate Only.

Also important with respect to facility operations is the assumption that any contaminant problem detected in the COA will be assessed and the appropriate response initiated (e.g. spill clean-up).

1.3.3 Emissions

Many of the various waste products and chemicals which may be present in the COA are described in the PARs listed above. For the purposes of this impact assessment, it is assumed that any chemical release constitutes contaminants which are potentially of concern to human health and/or the environment.

For the purposes of this report, all potential contaminants have been generically classified into one of the following groups:

1) Miscible - contaminants which are dissolved in ground water, and

2) Immiscible - contaminants that are essentially insoluble and therefore remain as a separate phase. These can be further divided into:

   - Light Non-Aqueous Phase Liquids (LNAPL) - contaminants which are less dense than ground water ("floaters"), and

   - Dense Non-Aqueous Phase Liquids (DNAPL) - contaminants which are more dense than ground water ("sinkers").

Many potential chemical releases will have more than one phase. Typically, an LNAPL or DNAPL will be only very slightly soluble in ground water rather than completely immiscible, therefore there will generally be a miscible component associated with every contaminant release.

The various ways that contaminants could be released into the environment from the COA facilities have been presented in the report "Site Selection Process Phase 4A: Selection of a Preferred Site(s) - Engineering" (Monenco Ltd. 1986g). These spill and leak event scenarios were further refined from a hydrogeologic standpoint through

meetings and discussions with OWMC and their engineering consultants. The resulting information is summarized in Appendix B.

2.0 IMPACT ON GROUND WATER FLOW

2.1 INTRODUCTION

Site clearing, leveling, drainage control, buildings, paved surfaces, subsurface structures, and granular backfill have the potential to locally alter the infiltration rate, water table depth, and direction and rate of ground water flow at the Preferred Site.
In this chapter, the potential ground water flow impacts for the various COA facilities are qualitatively assessed.

Section 2.2 presents an overview of the existing ground water flow conditions at the Preferred Site. Section 2.3 provides a discussion of potential ground water flow impacts associated with various components of the COA facility. The facility components are not considered individually, rather, groupings are presented into which each of the major COA facilities can be categorized.

Finally, Section 2.4 assesses whether the COA could potentially effect the availability of ground water in off-site wells.

2.2 EXISTING GROUND WATER FLOW CONDITIONS

Existing ground water flow conditions at OWMC's preferred site are documented in the report "Site Assessment - Phase 4B: Geology, Hydrogeology and Geotechnics-Baseline Conditions" (GLL 1987a), and are briefly summarized in this section.

The topography of the site is for the most part flat with relief provided by small ridges and swales. Table 2-1 presents the geologic and hydrostratigraphic units identified during the baseline studies.

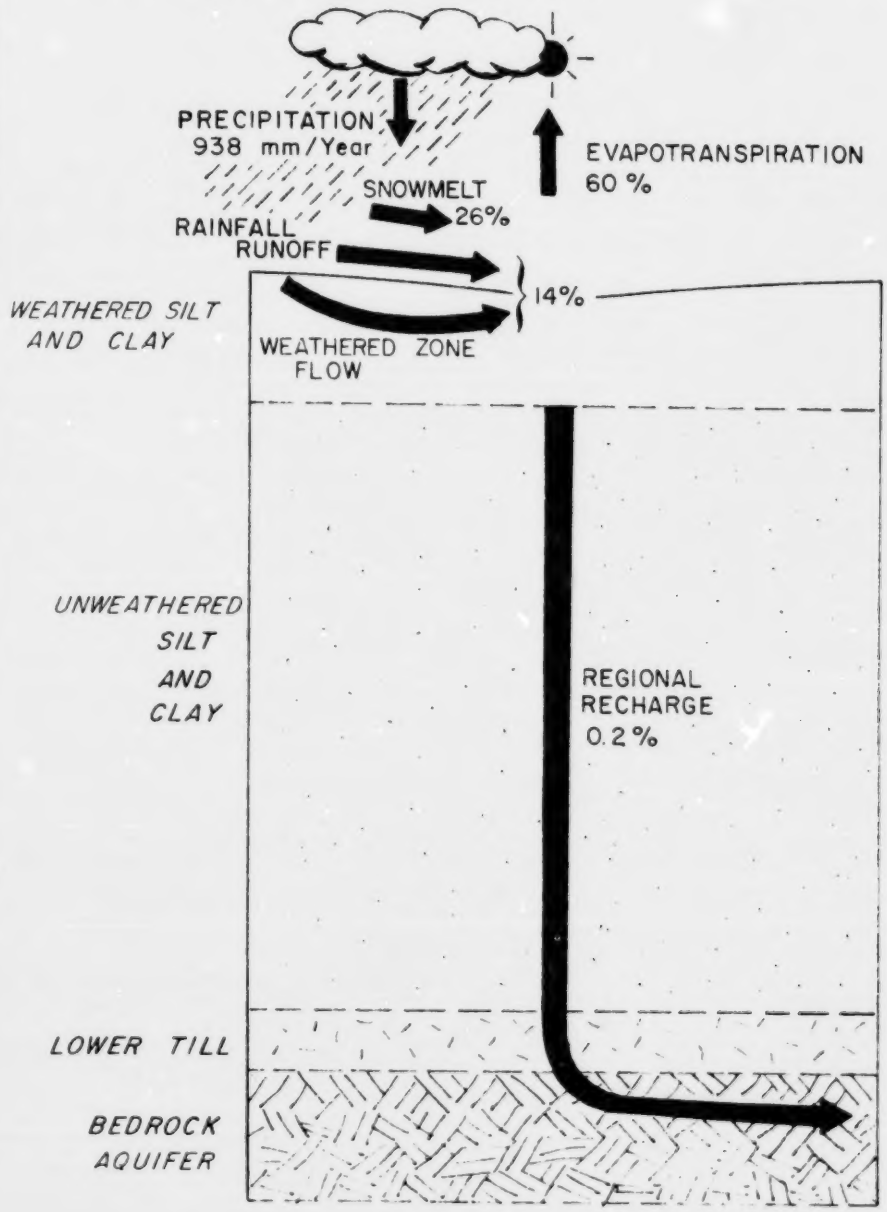
The topographic relief at the site and the physical properties of the hydrostratigraphic units are the controlling influences on ground water flow. Figure 2-1 is a schematic overview of ground water flow at the Preferred Site. As depicted, most of the precipitation which falls on the site either evapotranspires or remains near the surface and eventually leaves the site as surface water. Only a small fraction of the total precipitation moves to depth as regional recharge.

TABLE 2-1 MAJOR GEOLOGIC AND HYDROSTRATIGRAPHIC UNITS AT THE PREFERRED SITE

GEOLOGIC UNIT	GROUP	HYDROSTRATIGRAPHIC UNIT	TYPICAL DEPTH FROM SURFACE
UPPER GLACIOLACUSTRINE UNIT	Overburden Aquitard	WEATHERED SILT AND CLAY	0
			~5m
HALTON UNIT		UNWEATHERED SILT AND CLAY	
LOWER GLACIOLACUSTRINE UNIT			
			~33m
LOWER TILL		LOWER TILL	
			~35m
GUELPH FORMATION	Bedrock Aquifer	ZONE A	
			~41m
		ZONES B TO E	

Figure 2-1

Schematic Overview Of Ground Water Flow



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Ground water flow in the overburden at the Preferred Site has two basic components: a shallow (dynamic) component, and a deep (steady state) component. During major precipitation events the water table rises into the ridges which produces significant lateral hydraulic gradients in the surficial weathered silt and clay. The ridges act as micro ground water divides. Infiltration flows laterally through fractures towards discharge in adjacent swales, and eventually leaves the site as surface water. Between precipitation events the water table declines to near the base of the swales and shallow lateral flow is much less pronounced.

The shallow flow component described above acts as a buffer for transient recharge events, hence deep ground water flow can be considered as essentially steady state. The low permeability of the unweathered silt and clay results in an extremely slow rate (0.004 m/a)of ground water flow through the overburden aquitard.

Ground water flow in the bedrock aquifer is generally in a southerly direction.

2.3 INFLUENCE OF COA FACILITY COMPONENTS

The following hydrogeologic assessment of the COA facility components was developed with Monenco Ltd. to ensure consistency with the conceptual engineering design. The schematic diagrams presented in this section were also based on input from Monenco Ltd.

For discussion purposes, the COA has been divided into five hydrogeological categories.

These are:

(1) areas where no infiltration will occur and the water table will be artificially lowered by subsurface drains (buildings, tank farms and lined ponds),

(2) areas of reduced infiltration (paved areas),

(3) areas of similar infiltration to present (grassed areas),

(4) sub-surface structures such as buried service trenches, pits and sumps, and

(5) ditches.

The potential effects of these on the water table and shallow ground water flow are discussed in more detail in the following sections.

2.3.1 Buildings, tank farms and lined ponds

Approximately 28% (5 ha) of the COA will be buildings, tank farms or lined ponds. Schematic diagrams of the subsurface construction of these structures are shown in Figures 2-2, 2-3, and 2-4.

These structures are considered to be essentially impermeable: the buildings because of their roof and concrete floor; the tank farms because their bases will be concrete (possibly lined); and the ponds because they will be synthetically lined. Consequently no infiltration will occur into the soil through these structures. This will contribute to a localized depression in the water table below these structures.

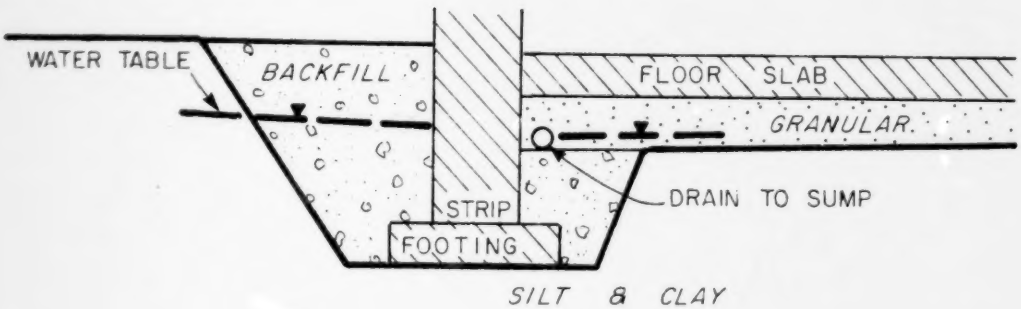
In addition, drains will be placed in the granular backfill below building and tank farm foundations to prevent the water table from rising and creating buoyant uplift on the underside of the foundation (Figures 2-2 and 2-3). These will also contribute to a localized depression in the water table below these structures. This effect will be most pronounced during wet periods when the water table adjacent to the foundation will be at its highest level compared to the level maintained by the drains below the foundation. Assuming a maximum water table near surface and drain depths of 1 to 2 m (Figures 2-2 and 2-3), the maximum water table depression will be on the order of 1 to 2 m. Throughout most of the year it will be less.

Since some ponds (e.g. storm water) may be empty during drier seasons, it will be necessary to lower the water table beneath the ponds during these periods so that the liners are not uplifted. This will be accomplished by pumping the lower granular layer of the liner as shown in Figure 2-4.

Figure 2-2

SCHEMATIC SECTIONS OF FOOTINGS FOR BUILDINGS

NOT TO SCALE



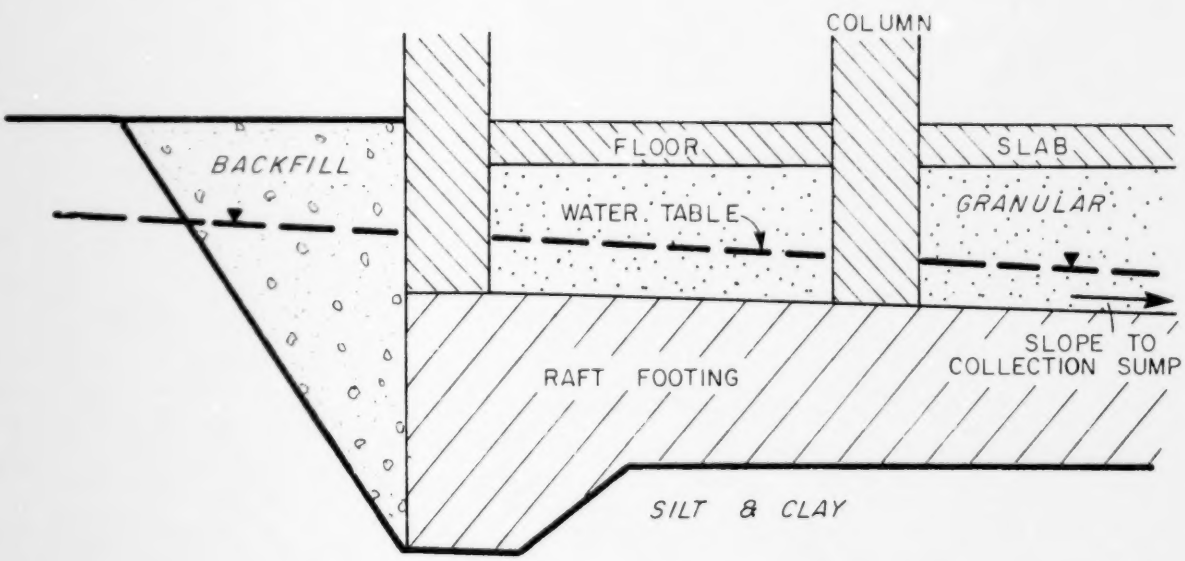


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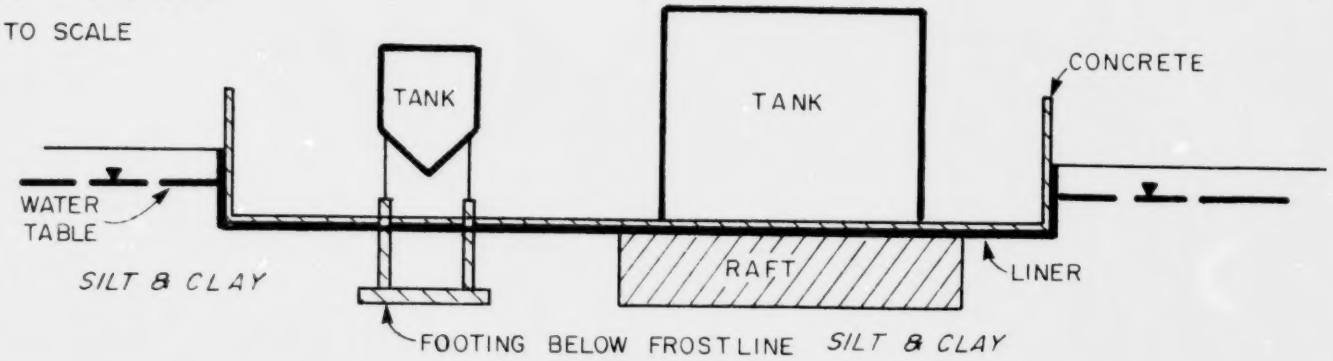
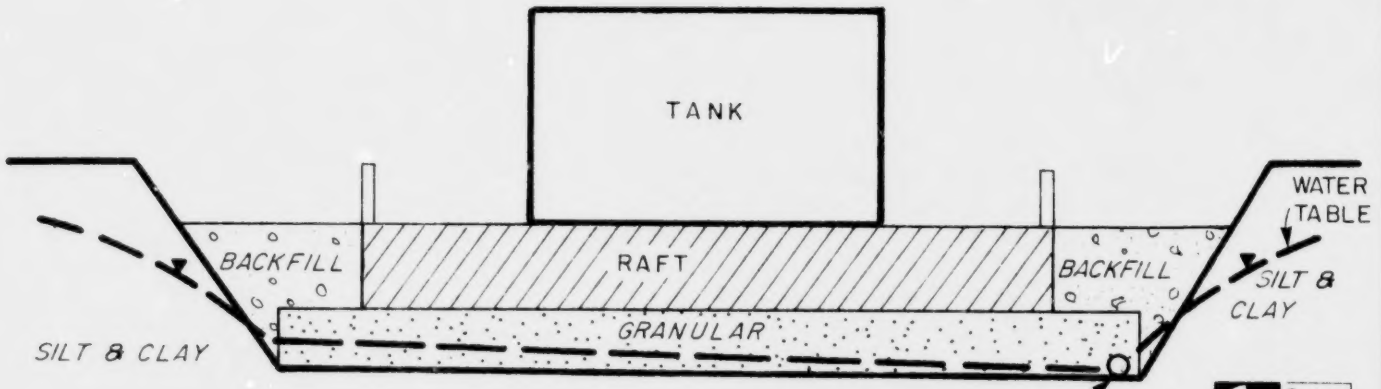
Figure 2-3

POSSIBLE CONFIGURATIONS OF TANK FARM FOOTINGS

NOT TO SCALE





*TYPICAL FROST PENETRATION DEPTH

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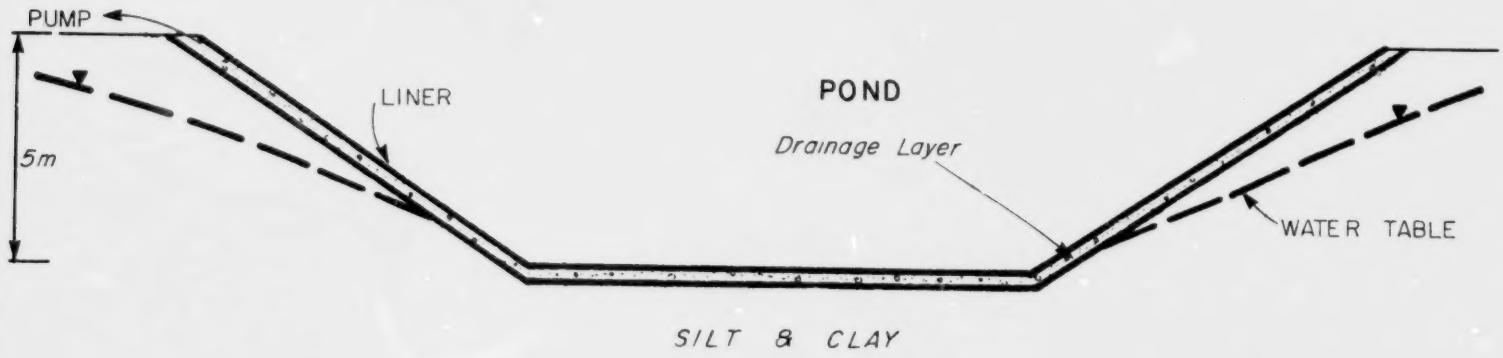
Figure 2-4

SCHEMATIC SECTION OF LINED PONDS

NOT TO SCALE



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This will result in a significant water table depression directly below the ponds (up to 5 m depending on pond depth). However, the effect should be localized laterally to within several metres of the pond. This is because of the relatively low permeability of the weathered clayey soils, seasonal pumping and because the ponds will be surrounded by grassed areas, through which substantial infiltration can occur to maintain the water table near its natural depth.

2.3.2 Paved Areas

Approximately 40% (7.4 ha) of the COA will be paved. Typically the asphalt will be placed over a thin (≤0.5 m) layer of granular material placed on grade.

The asphalt surface will reduce infiltration. However, it is unlikely that the average water table depth will be significantly reduced below these areas. This is because asphalt is not impermeable and allows some infiltration. Very little of the infiltration presently occurring is actually required to maintain the water table. Most of this infiltrated water likely moves laterally a short distance and then discharges to the swales as discussed in Section 2.2. The small amount required to maintain the water table is still anticipated to infiltrate through the asphalt.

2.3.3 Grassed Areas

Approximately 32% (5.8 ha) of the COA will be grassed or landscaped. Infiltration through these areas is anticipated to be similar to present conditions and therefore should have no significant effect on the water table.

2.3.4 Buried Services, Pits and Sumps

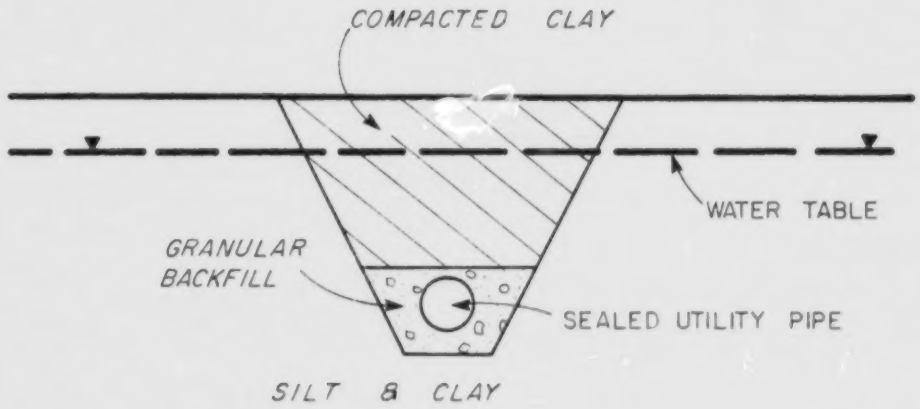
Buried utility corridors are proposed for the Preferred Site. A typical profile of a utility trench is shown in Figure 2-5. As indicated in the figure, the construction of these underground corridors should not have a significant influence on the local ground water table provided seals are installed at various locations to prevent the granular backfill from acting as a preferential route for lateral ground water flow.

Beneath some of the buildings, tank pits and sumps are proposed in order that any leakage within the process area can be monitored and collected. These pits and sumps

Figure 2-5

SCHEMATIC OF UTILITY TRENCHES

NOT TO SCALE



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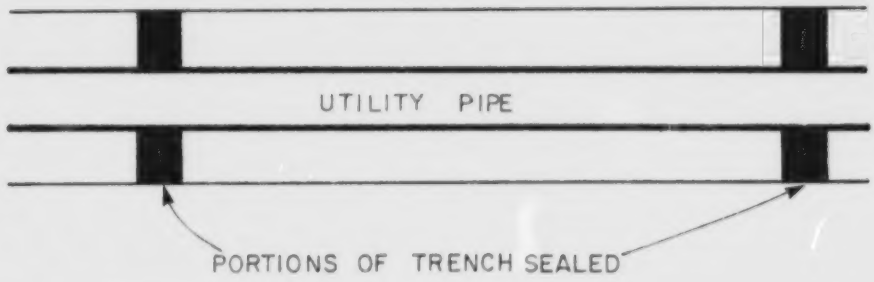

PLAN

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will be maintained in a dry condition. The outside wall of the sump may be lined with a synthetic membrane to reduce the amount of inflow of uncontaminated ground water. Therefore, there should be very little influence on the local water table. A schematic of a proposed sump is shown in Figure 2-6.

2.3.5 Ditches

Ditches will be present within and around the outside of the COA particularly adjacent to the roads. These ditches will act like the existing swales to provide a local shallow ground water divide and collect shallow ground water.

2.4 EFFECTS ON GROUND WATER AVAILABILITY

2.4.1 Weathered Silts and Clays

There are some shallow, large diameter wells in the area which collect at least part of their water from the weathered silts and clays. The nearest such well presently in use is located about 250 m to the northwest of the Preferred Site.

The effects of the COA on the water table and shallow ground water flow in the weathered silts and clays will be minor and localized. These effects will not extend off-site since the COA is about 175 m from property boundaries. Consequently the availability of ground water in shallow overburden wells will not be affected by the COA.

2.4.2 Bedrock Aquifer

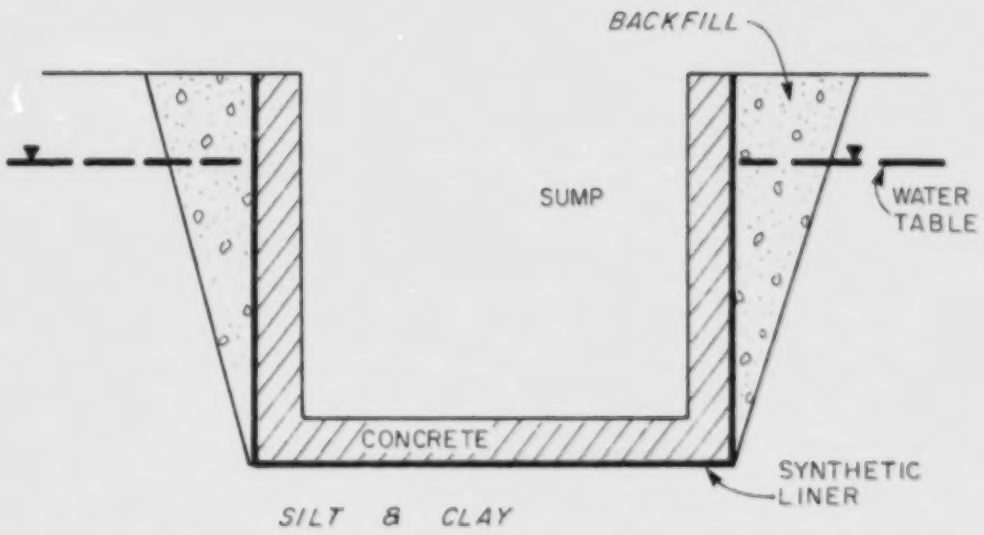
The minor, localized effects of the COA on the water table and shallow ground water flow are not anticipated to have any measurable effect on the bedrock flow system and therefore will not affect the availability of ground water in bedrock wells.

For example, consider the worst case scenario of a 2 m reduction in the water table under the entire COA. This would reduce the amount of downward recharge below the COA by less than 0.5 mm/a and the effect on the aquifer would be negligible.

Figure 2-6

SCHEMATIC SECTION OF SUMP

NOT TO SCALE



NOTE 1- LINER MAY BE INSTALLED ON OUTSIDE WALL OF PIT
2- NO PERIMETER DRAINS

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3.0 POTENTIAL IMPACTS ON GROUND WATER QUALITY

3.1 INTRODUCTION

The COA facilities are being designed with the intent of minimizing failures, spills and leakage into the subsurface. This in turn will minimize potential ground water impacts. This is being accomplished through a design based on past experience and compliance with the most stringent of existing standards and regulations. As well, recognizing that subsurface structures such as waste receiving bins may eventually leak, these components have been designed with double containment systems. Appendix A provides a list of the engineered primary and secondary containment systems that will be constructed at the site and the operational considerations that will be utilized to minimize the possibility of contaminant emissions. The integrity of all components will be monitored throughout the facility life and repaired, replaced or upgraded as required. Consequently, it is reasonable to assume that engineered containment will be a feasible approach to controlling subsurface contamination at the COA. Also, spills and leaks will be cleaned up as soon as they occur to levels deemed acceptable by regulations and by event-specific impact assessments.

Despite these precautions, the assessment of potential ground water impacts outlined in this Chapter assumes that some inaccessible spills and undetected leakage may occur in localized areas. For example, a spill beside a building may result in some product accumulating under the building. In most cases it would not be practical to excavate the building to gain access to the spilled material nor may methods of remotely extracting the product be totally effective. Consequently some product may remain in the ground under the building until the building is knocked down and the product and contaminated soil are removed during decommissioning. Examples of other potential emissions scenarios, no matter how unlikely, are given in Appendix B. This Chapter assesses whether these inaccessible spills and undetected leaks will result in a ground water impact before they are cleaned up during decommissioning. The operating life of the facility is assumed to be 50 years.

A very large variety of contaminants will be present at the COA in different amounts, forms and mixtures. Therefore it is not practical to assess potential impacts on a

chemical by chemical basis. From the perspective of potential spillage or leakage into the subsurface it is mainly liquids that are of concern. From a hydrogeologic perspective these can generally be grouped into two categories; miscible and immiscible. Miscible constituents dissolve in the ground water and are usually transported with the ground water in the direction of flow. (The exception is diffusion against very slow flow.) Most inorganic fluids fall into this category as well as many organics. Immiscible liquids are essentially insoluble in the ground water and therefore remain as a separate phase. Although affected by the ground water regime, their movement can be independent of the direction of ground water flow. This category applies mostly to organic fluids. It should be noted, however, that immiscible constituents do have some finite, although small, solubility in water. Therefore there will generally be some miscible component associated with an immiscible phase. This Chapter considers the subsurface migration and potential effects on ground water of both immiscible (Section 3.3) and miscible (Section 3.4) constituents.

3.2 EXISTING GROUND WATER QUALITY

During the Phase 4B Geoscience program, general chemistry, ion concentration, and environmental isotope data were collected for the ground water at the Preferred Site. The resulting characterization of the existing ground water quality at the Preferred Site is described in detail in the report entitled "Site Assessment - Phase 4B: Geology, Hydrogeology and Geotechnics, Baseline Conditions" (GLL 1987a). The following is a very brief summary extracted from that report.

The ground water geochemistry can be grouped into three main categories based on the site hydrostratigraphy:

- shallow overburden water quality,
- deep overburden water quality, and
- bedrock water quality.

Table 3-1 presents the general chemistry and major ion concentrations of all three categories of ground water.

TABLE 3-1: MAJOR ION CONCENTRATIONS AND GENERAL CHEMISTRY OF GROUND WATERS AT THE PREFERRED SITE

PARAMETERS (all concentrations in mg/L unless otherwise noted)	SHALLOW OVERBURDEN GROUND WATER (BASED ON STANDPIPES)[1]		DEEP OVERBURDEN GROUND WATER (AT 25 M DEPTH)		BEDROCK GROUND WATER (UPPER 3 M)[2]		ONTARIO DRINKING WATER OBJECTIVES
	RANGE OF VALUES	AVERAGE	RANGE OF VALUES	AVERAGE	RANGE OF VALUES	AVERAGE	
1. GENERAL CHEMICAL INDICATORS							
• pH (unitless)	6.9 to 7.4	7.1	8.0 to 8.6	8.2	7.3 to 7.7	7.4	-
• temperature (°C)	11 to 13	12	10 to 13	11	10 to 13	11	15[5]
• conductivity (umhos/cm)	6100 to 10000	8213	1110 to 1600	1365	2100 to 2660	2318	-
• total dissolved solids	8940 to 19600[4]	15255	806 to 1260	1041	2360 to 2960	1681	500[5]
• hardness[3] (as $CaCO_3$)	5307 to 9742	7457	166 to 381	274	1034 to 1463	1280	500[6]
• dissolved inorganic carbon	110 to 210	167	6 to 17	13	16 to 26	21	-
2. MAJOR CATIONS							
• calcium (Ca)	335 to 434	398	42.3 to 92.9	68	325 to 382	353	-
• magnesium (Mg)	1090 to 2450	1575	14.7 to 37.3	25.4	96.5 to 124	110	-
• potassium (K)	5 to 11	8	<1 to 2	<1	<1 to 5	2.7	-
• silicon (Si)	5.86 to 7.81	6.72	3.21 to 4.02	3.49	3.60 to 4.63	4.04	-
• sodium (Na)	292 to 545	387	160 to 235	190	131 to 179	152	20[7]
• strontium (Sr)	7.33 to 11.40	9.25	0.95 to 1.98	1.46	7.90 to 9.99	9.13	-
3. MAJOR ANIONS							
• chloride (Cl)	7.3 to 18.2	11.6	18.8 to 37.3	27.9	28.7 to 49.9	41.4	250[5]
• fluoride (F)	4.68 to 7.60	6.27	0.83 to 1.18	0.97	2.14 to 2.73	2.37	2.4[8]
• sulphate (SO_4)	5280 to 9370	7323	400 to 760	598	1370 to 1650	1502	500[5]
• bicarbonate (HCO_3)[9]	753 to 880	795	44 to 69	57	63 to 111	85	-

1. Results from 85-10-10 not included because of surface water leakage into monitor.
2. Results from 85-1-1 not included because of possible dilution with drilling water.
3. Calculated from Ca and Mg using: total hardness = 2.5 Ca + 4.1 Mg (Freeze and Cherry, 1979, pg. 387).
4. Underlined concentrations exceed the Ontario Drinking Water Objectives.
5. Maximum desirable concentrations for parameters related to aesthetic quality.
6. Not an Ontario Drinking Water Objective, but levels in excess of this considered very poor for most domestic purposes due to incrustation and excessive soap consumption (Ontario Ministry of the Environment, 1983, pp. 40 to 41).
7. Not an Ontario Drinking Water Objective, but at levels above this, people on sodium restricted diets should consult their physician (Ontario Ministry of the Environment, 1983, pg. 28).
8. Maximum acceptable concentrations for parameters related to health.
9. Calculated from alkalinity.

The shallow overburden ground waters are characterized by very high total dissolved solids to a depth of about nine metres. This is a result of intensive weathering near the surface and many thousand years of downwards advective and diffusive transport. Inspection of the ranges of values shown in the table indicates that the ground water quality is quite variable in this zone. In general, the ground water in the shallow overburden is considered to be of poor quality for drinking water.

Deep overburden ground waters occur from a depth of about nine metres down to the top of the underlying bedrock. These are characterized by much lower total dissolved solids and much less overall variability than in the shallow overburden. The total dissolved solids continue to decline with depth in the deep overburden.

Ground water quality data were collected for the upper three metres of bedrock, which is the zone where most water wells in the area of the Preferred Site obtain their water supply. The data proved to be quite consistent spatially at the Preferred Site. The bedrock ground water is considered to be marginal as a drinking water source since it exceeds the Ontario Drinking Water Objectives in several instances, although most of these are related to aesthetic quality only.

Environmental isotopes (tritium, Oxygen-18, and deuterium in this case) were also assessed during the Phase 4B Geoscience program. Tritium was detected in shallow ground water down to a depth of three to five metres. No tritium was detected below this depth in the overburden or bedrock ground water. Tritium is an indicator of water recharged since the early 1950s. This implies that the zone of recent recharge and "active" ground water flow in the shallow subsurface does not extend below about five metres.

Oxygen-18 and deuterium isotope contents of the overburden ground waters decline uniformly with depth from values typical of modern, temperate precipitation at the water table to values near those representative of colder glacial water. This indicates that solute transport downward through the unweathered silt and clay is very slow, since even after about 8,000 to 10,000 years of downward ground water flow (i.e., since the

climate warmed after glaciation), ground waters deep in the overburden still retain part of their glacial isotopic character.

The trends observed for oxygen-18 and deuterium at the Preferred Site are similar to those found by other investigators of thick, low permeability, clayey deposits in Ontario with similar ground water velocities (Crooks and Quigley, 1984; Desaulniers et al., 1981; Desaulniers, 1986; Heystee and Johnston, 1984; and Johnson et al., 1986 for example). These investigators have shown from these trends, as well as age dating and trends of other ionic constituents that due to the very slow ground water velocities in these types of deposits solute transport by diffusion is equally or more important than by advection and that solute dispersion occurs only by diffusion. This will also be the case at the Preferred Site.

More positive oxygen-18 and deuterium values in the bedrock indicate that its ground water is at least partly recharged from upgradient areas.

3.3 POTENTIAL EFFECTS FROM IMMISCIBLE FLUIDS

Immiscible fluids can be divided into two groups; light non-aqueous phase liquids (LNAPL) which are less dense than the ground water ("floaters"), and dense non-aqueous phase liquids (DNAPL) which are denser than the ground water ("sinkers").

3.3.1 LNAPL

The most common LNAPLs are petroleum products (oils, gasoline and other fuels which will be present at the COA as both wastes and products used in operating the facility) and non-halogenated solvents (benzene, xylene). Based on the UCD waste classification system outlined in OWMC (1982 and 1983), the most likely waste categories that will contain LNAPLs at the COA are categories 214 to 216, 245, 248, 251, 261 to 264, 281, 282 and 289. These categories are described in Appendix D.

Because LNAPLs are less dense than the ground water and immiscible, they will not migrate deeper than the lowest water table level. The lowest water table depth measured at the Preferred Site during baseline studies has been about 3m. Allowing for the possibility of a 1 to 2 m lower water table in localized areas of the COA (Section

2.3), LNAPLs from an inaccessible spill or undetected leak should not penetrate below a maximum of about 4 to 5 m.

To illustrate the extent of lateral movement consider the most probable scenario for an inaccessible spill or undetected leak where the LNAPL is in a granular backfill below a foundation and the water table is within the fill. In this scenario the LNAPL will rapidly penetrate downward to the water table due to the permeable nature of the backfill. At the water table it will spread laterally along the water table surface, ideally in the shape of a pancake. The thicker part of the pancake will be near the source of the spill or leak. The direction of spread is usually greatest in the direction in which the water table is sloping. However, LNAPLs also tend to follow the path of least resistance. Therefore it can be anticipated that the LNAPL will preferentially spread on top of the water table mainly within the backfill material. Whether the LNAPL will spread over the entire backfill area will depend upon the size of the area and the amount of LNAPL involved. There will be little tendency for lateral migration beyond the foundation backfill into surrounding native soils because the native clays have a much lower permeability. As well, the water table is anticipated to be slightly depressed below foundations (Section 2.3.1) contributing to containment of the LNAPL below the foundation.

However, where there are permeable fills connected to the foundation backfill such as in service trenches, LNAPLs may migrate away from the source area along these pathways. Movement through service trench backfills should be mitigated by placing seals at strategic locations in the trench as discussed in Section 2.3.4.

Below some foundations it is also planned that there will be drains to control ground water as discussed in Section 2.3.1. If the water table rises to the level of these drains, which it is expected will happen at least seasonally, then these drains will also tend to collect any LNAPL present in the subsurface. This is a potential pathway for the LNAPL to enter the sewer either through direct connection of the drains or via sump pump discharge. This possibility has been recognized and is one of the reasons the water coming from the COA sewer has been designated "potentially contaminated". This water will be collected, tested and treated if necessary before release (Monenco

Ltd. 1987). If a sump pump system is used, the sump should be periodically inspected for the presence of LNAPL or evidence of ground water contaminated by LNAPL. Consideration should also be given to using explosion proof sump pumps since most LNAPLs release potentially explosive vapours.

It is not expected that off-site migration of LNAPL will occur in the subsurface due to an inaccessible spill or undetected leak. This is because:

(1) it is assumed that short circuit pathways such as service trench backfills will be mitigated,

(2) the COA will be surrounded by ditches which seasonally intercept the water table and therefore will intercept the LNAPL, leading to detection and subsequent remedial action,

(3) the clayey nature and relatively low permeability of the weathered soils at the Preferred Site will act to retard movement and retain immiscible phases, and

(4) the COA is a substantial distance from site boundaries (175 m).

3.3.2 DNAPL

DNAPLs comprise a large portion of the organic fluids presently considered hazardous. For example, of the compounds on the U.S. E.P.A.'s Priority Pollutant List that are liquids, all but a few are DNAPLs. These include the halogenated compounds (i.e., those containing chlorine, bromine, fluorine etc.) such as the aliphatics (e.g., 1,1,1 trichloroethane), ethers (e.g., bis[2-chloroethyl]ether), aromatics (e.g., chlorobenzene, chlorophenol), and biphenyls (e.g., PCBs), as well as non-halogenated compounds such as phthalate esters (e.g., di-n-butyl phthalate) and polycyclic aromatic hydrocarbons (e.g., naphthalene). Based on the UCD waste classification system outlined in OWMC (1982 and 1983), the most likely waste categories that will contain DNAPLs are 211 to 213, 221 to 224,242, 245, 247, 257, 258, and 262. These categories are described in Appendix D.

Because DNAPLs are denser than water the water table is not a lower boundary to movement as it is for LNAPLs. The question is: "How deep might a DNAPL migrate before it is cleaned up during decommissioning?" This is relevant to both assessing potential impacts on the bedrock aquifer and in planning decommissioning strategies.

Penetration of the DNAPL to the base of the weathered zone (i.e., about 5 m) is likely to occur locally in the vicinity of the DNAPL source. This is because the presence of fractures in this zone enhance its permeability. DNAPLs tend to migrate down through the larger pore spaces (fractures in this case) while the ground water tends to remain in the smaller pores (the clayey matrix).

It is not anticipated that DNAPLs will penetrate any appreciable distance into the unweathered silts and clays below the COA. These soils are unfractured and therefore movement would have to take place through the pores. For the DNAPL to migrate through the pore spaces it must first displace the pore water (since we are discussing movement below the water table). Since the DNAPL phase is immiscible in water, this displacement is very difficult especially in the very low permeability clayey soils present at the Preferred Site where the very small pore sizes result in high capillary ground water pore pressures (i.e., a high capacity for water retention). Therefore migration of DNAPL downward below the weathered zone is likely to occur only by the very slow process of diffusion.

In support of this, recent research at the Institute for Ground Water Research at the University of Waterloo placed a DNAPL (trichloroethylene) in a borehole in contact with in-situ unweathered clayey till (Dr. Cherry, personal communication). No loss of the DNAPL was observed over an eight month period of observation indicating that the DNAPL did not penetrate into the saturated, unweathered clayey soils.

Laboratory experiments over the last decade imply that concentrated organic phases alter the permeability of clays, making them more permeable. As well, some clay liners at hazardous waste landfills have been suspected to be leaking due to organic liquids-clay interactions. However, for these effects to occur the organic must first migrate through the pores of the clay so that the clay grains come in contact with the organic.

As discussed above it will be very difficult for this to occur at the Preferred Site. As well many of the experiments reported in the literature evaluated dry or partially saturated, recompacted soils at unrealistically high pressures to force the organic through the soil. The liners suspected to be altered by organics were thin (a few metres), were recompacted (i.e., higher permeability than under native conditions) and likely were partially saturated and contained fractures. None of these conditions are applicable to the unweathered silts and clays at the Preferred Site.

The most significant potential route for DNAPLs to reach and impact the bedrock aquifer is down "short circuits" through the unweathered overburden. These are existing boreholes and ground water monitors installed in the COA to establish baseline conditions, future geotechnical holes installed for detailed design of each structure and deep subsurface structures (like pile foundations if used). Consequently these holes must be properly sealed. The mitigation of abandoned boreholes and monitors is discussed in our report on ground water management strategies (GLL 1987e).

With respect to lateral migration, DNAPLs, like LNAPLs, tend to follow the path of least resistance. As well, they are redirected by permeability contrasts. Therefore, DNAPLs will tend to accumulate in and migrate laterally in permeable fills because of the permeability contrast between the fills and the surrounding lower permeability clay. Like LNAPLs, lateral migration along service trenches should be mitigated by installing seals in the trenches at strategic locations. Lateral spreading of the DNAPL under foundations can be anticipated, although the extent of spreading will depend upon the size of the backfill area and the amount of DNAPL present. In this regard, collection of some of the DNAPL by the sub-drains under the foundations might occur, particularly where the drain level is at the backfill-clay contact. This could discharge into the "potentially contaminated" sewer in the same fashion as discussed for LNAPLs (Section 3.3.1).

Lateral migration in the weathered silts and clays will likely be limited. This is because the tendency of DNAPLs is to move downward (at least to the bottom of the weathered zone). As well, since there is really no sharp contact between weathered and unweathered soils lateral movement along this boundary will not be enhanced. Also,

movement will be mainly via fractures. The lateral connectivity and frequency of fractures decreases towards the base of the weathered zone. As well, adsorption of the DNAPL on the soil will act to restrain movement. Consequently lateral migration of DNAPL off-site is considered unlikely from an inaccessible spill or undetected leak, particularly when you consider that the COA is at least 175 m from site boundaries.

3.4 POTENTIAL EFFECTS FROM MISCIBLE CONSTITUENTS

As noted earlier, immiscible constituents do have some finite, although small, solubility in water. Therefore contaminants will dissolve in the ground water immediately adjacent to any inaccessible spill or undetected leak of a LNAPL or DNAPL. As well, inaccessible spills or undetected leaks of aqueous wastes or concentrated soluble wastes (or reagents) will also dissolve in the ground water.

To assess whether these miscible components could potentially impact the bedrock aquifer prior to decommissioning the analytical contaminant transport model PATSOURCE was used. This model is documented in Appendix C. The conditions assumed for this modelling assessment were:

(1) non-reactive contaminant transport,

(2) penetration of the leak or spill to the base of the weathered silt and clay (5 m) is instantaneous,

(3) the source of contamination occurs over a finite area (a "patch") of 10 x 10 m,

(4) the source lasts for 50 years, and

(5) the ground water flow and dispersion parameters were as follows;

- diffusion coefficient (average literature value) = 6×10^{-10} m^2/s
- longitudinal dispersivity = 0
- transverse dispersivity = 0
- downward average linear ground water velocity (from baseline studies). = 1.2×10^{-10} m/s

The above conditions would be considered the worst case scenario since in reality;

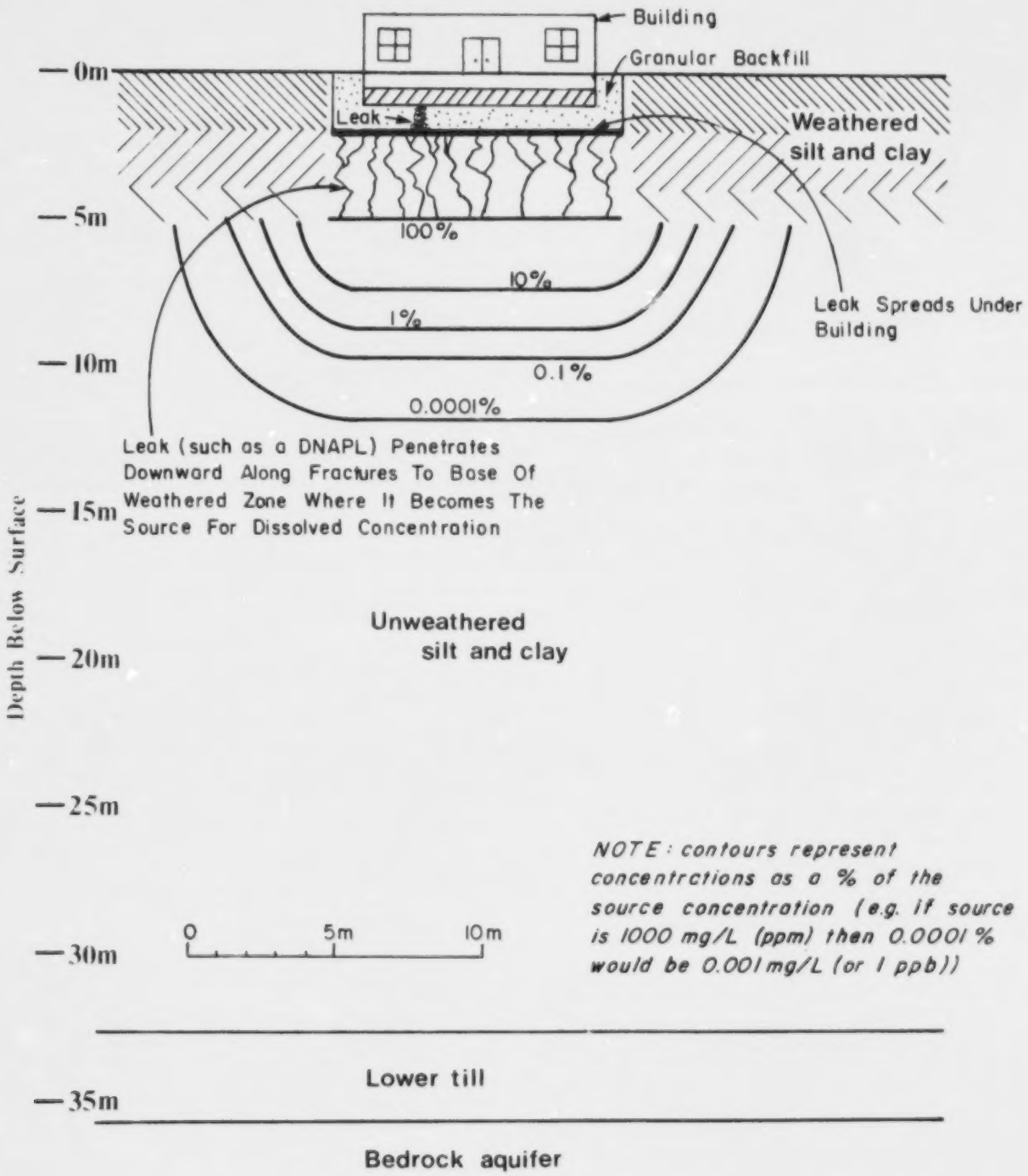
(1) not all leaks or spills will penetrate to the base of the weathered zone

(2) most leaks and spills will not exist over the entire facility life (i.e., 50 years), and

(3) few contaminants will be non-reactive.

The predicted concentrations with depth in the ground water of the unweathered silts and clays are shown in Figure 3-1. The concentrations are given as a percentage of the source concentration. The source is assumed to be 100%. In cases involving immiscible product such as a LNAPL or DNAPL, 100% would approximate the solubility of the constituent in the ground water. The concentration contour used to assess the depth of significant contaminant migration over 50 years was 0.0001%. This was selected because many LNAPLs and DNAPLs are potentially of concern at concentrations of 0.001 mg/L. These same constituents have solubilities in the range of 1000 mg/L or less (0.001 mg/L divided by 1000 mg/L x 100% = 0.0001%). The depth of the 0.0001% concentration contour after 50 years is about 6.5 m below the base of the weathered zone or at a total depth of 11.5 m. Sensitivity analyses with different sizes of sources indicated that the depth of contaminant migration did not vary significantly for other sizes. Since the thickness of the overburden at the Preferred Site is between 30 and 35 m, then no impact on the quality of the underlying bedrock ground water is predicted to

FIGURE 3-1 Extent Of Contamination From A Continuous Leak With An Assumed Spread Of 10m x 10m Over 50 Year Life Of Facility (No Sorption)



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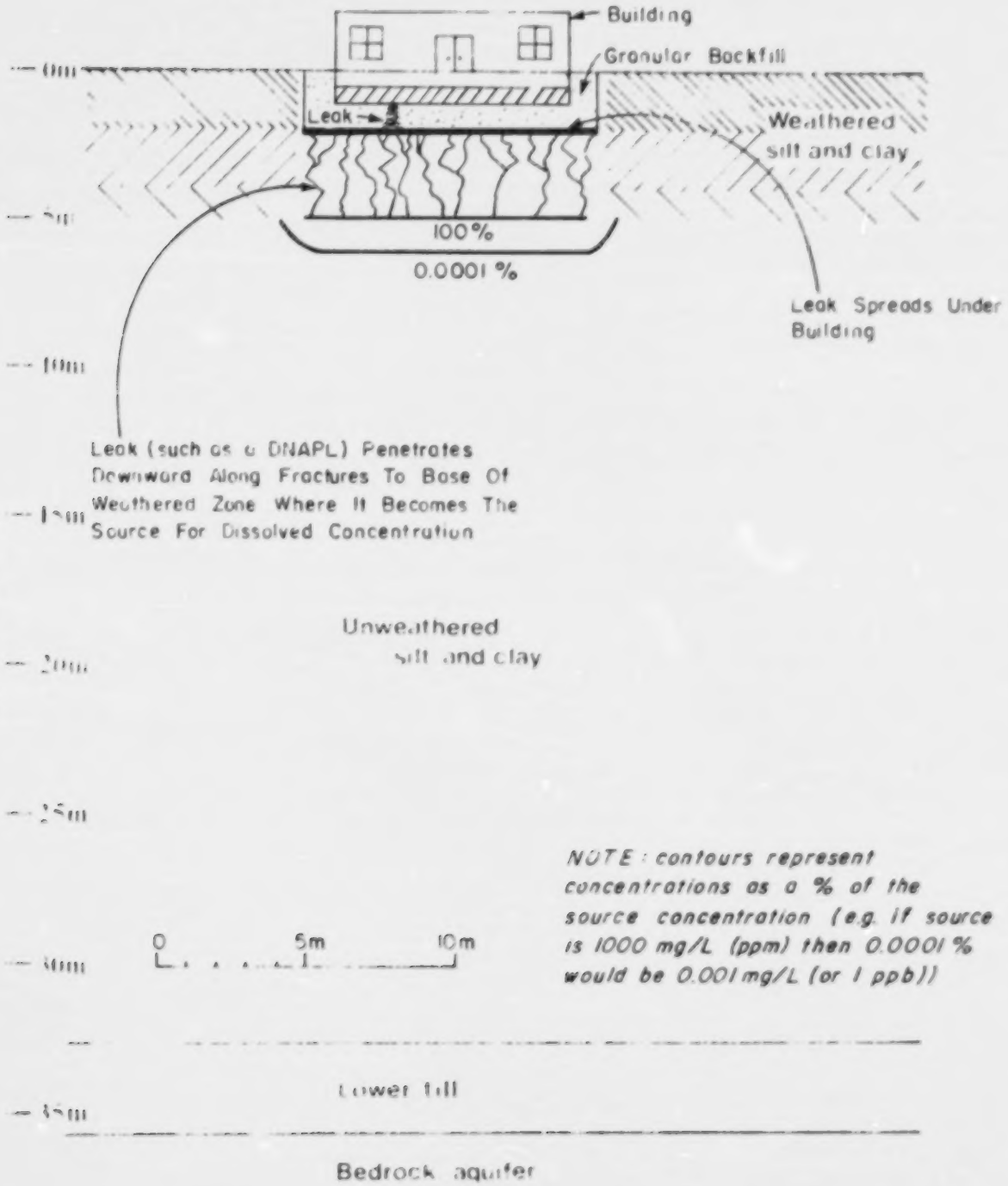
occur from inaccessible leaks and undetected spills during the operating life of the facility, even with this worse case scenario.

In reality sorption of most contaminants will occur. Johnson et al (1986) investigated the migration of several organic compounds into the ground water of an unweathered clayey till below a waste cell at the Tricil Ltd. facility near Sarnia, Ontario. The compounds they analyzed for were; toluene, ethylbenzene, trichloroethylene, 1,2-dichloropropane and naphthalene. These compounds would be expected to exhibit only minor sorption. As well, toluene and ethylbenzene are common LNAPLs when in concentrated form and the others are common DNAPLs. They found that the effective diffusion coefficient (which includes sorption effects) for all of these compounds was on the order of 1×10^{-11} m^2/s or less (to as low as 2×10^{-12} m^2/s). In the five years since the waste had been deposited, these organic contaminants had only penetrated about 0.15 m into the unweathered clayey till below the waste. At the same time, chloride from the waste, which is a conservative constituent exhibiting no sorption, had migrated about 7 times further, to a depth of about 1 m.

To assess the more realistic case where sorption occurs, the model PATSOURCE was again used with the same conditions as described previously, except that the effective diffusion coefficient used was 1×10^{-11} m^2/s (the maximum determined by Johnson et al. (1986)). The results of this assessment are shown in Figure 3-2. In this case the 0.0001% concentration contour is at a depth of only 1 m into the unweathered silt and clay below the weathered zone, or at a total depth below grade of about 6 m. This further illustrates that inaccessible spills and undetected leaks in the COA should not impact the bedrock aquifer prior to decommissioning.

As can be seen from Figure 3-1 lateral migration of miscible contaminants in the ground water of the unweathered silt and clay is essentially insignificant. There is potential for lateral migration of contaminated ground water in the shallow, weathered silt and clay, however, this is anticipated to be localized with little potential to migrate off-site. This is because;

FIGURE 3-2 Extent Of Contamination From A Continuous Leak With An Assumed Spread Of 10m x 10m Over 50 Year Life Of Facility (With Sorption)


Building
Granular Backfill
Leak
Weathered silt and clay
100%
0.0001 %
Leak Spreads Under Building
Leak (such as a DNAPL) Penetrates Downward Along Fractures To Base Of Weathered Zone Where It Becomes The Source For Dissolved Concentration
Unweathered silt and clay
0
5m
10m
NOTE : contours represent concentrations as a % of the source concentration (e.g. if source is 1000 mg/L (ppm) then 0.0001 % would be 0.001 mg/L (or 1 ppb))
Lower till
Bedrock aquifer

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(1) Shallow ground water flow directions should be inward toward building foundations because of localized water table depressions under the buildings (Section 2.3.1). This will prevent outward lateral migration of contaminated ground water. However, it should be noted that shallow subsurface drains in the foundation backfill will collect contaminated ground water which would discharge to the potentially contaminated sewer.

(2) Preferential migration along the permeable backfills of service trenches would be limited by the placement of seals at strategic locations in the trenches.

(3) The COA is about 175 m from the site boundaries. In this intervening area will be the landfill, with a 5 m cover of native clay finished at grade and regraded to simulate the existing ridge and swale topography. As well, there will be several ditches. Consequently there will be several shallow ground water divides between the COA and the site boundary, all which would act to "capture" and dilute any contaminated shallow ground water.

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 CONCLUSIONS

This report assesses potential impacts of the Central Operating Area on both the availability of ground water in off-site wells and the quality of the ground water. The assessment of potential effects on availability assumes that ground water from the Preferred Site will not be used as a water supply for the facility. The assessment of potential effects on quality assumes that OWMC will clean-up, repair and remediate subsurface contamination from spills and leaks as they occur and that the Central Operating Area will be decommissioned after 50 years to levels deemed acceptable by regulations and site specific decommissioning impact assessments. Therefore the ground water quality assessment focused only on potential effects of undetected leaks and inaccessible spills over the 50 year life of the facility. The main conclusions of this assessment are as follows:

(1) The Central Operating Area will not affect the availability of ground water in off-site wells.

(2) The most significant potential route for contaminants to reach and impact the quality of ground water in the bedrock aquifer is down "short circuits" through the unweathered overburden. These are existing boreholes and monitors installed in the Central Operating Area to establish baseline conditions, future geotechnical holes installed for detailed design of each structure and deep subsurface structures such as foundation piles, if used.

(3) Assuming no "short circuits", undetected leaks and inaccessible spills in the Central Operating Area will not have an impact on ground water quality in the bedrock over the facility life. This applies to both concentrated products such as immiscible fluids and constituents dissolved from these leaks and spills in the ground water.

(4) Shallow ground water within the weathered overburden may become locally contaminated within the Central Operating Area due to inaccessible spills and

undetected leaks. The most significant potential route for contaminants to migrate laterally in the shallow ground water of the weathered overburden is via the permeable backfill of subsurface service trenches. However, assuming that service trenches are sealed, no impacts on the shallow ground water off-site should occur. Nor should concentrated products such as immiscible fluids migrate off-site due to inaccessible spills and undetected leaks.

(5) Sub-drains under foundations are a potential route for both concentrated product and contaminated ground water associated with inaccessible spills and undetected leaks to discharge to the "potentially contaminated" sewer, if these drains connect directly to the sewer of if sump pumps discharge to the sewer.

4.2 RECOMMENDATIONS

Based on the conclusions of this study our recommendations are as follow:

(1) Existing "short circuits" (i.e., boreholes and monitors) through the overburden should be sealed prior to facility construction. Guidance on sealing existing boreholes and monitors is given in GLL (1987e). All future holes and deep foundations should also be properly constructed and sealed to prevent these from becoming "short circuits".

(2) All subsurface service trenches should be sealed to reduce any potential for lateral contaminant migration. Methods for sealing the backfill of service trenches should be evaluated to select methods effective in preventing preferential lateral migration of both miscible and immiscible products.

(3) The surface water monitoring and management program should take into consideration the potential for contaminants to enter the "potentially contaminated" sewer through foundation sub-drains.

(4) OWMC should develop a ground water and soil monitoring program for the Central Operating Area to monitor for potential impacts during the facility life and monitor the effectiveness of clean-up and decommissioning actions.

Guidance on monitoring strategies is provided in our report "Ground Water Management Strategies" (GLL 1987e).

5.0 REFERENCES

Crooks, V.E. and R.M. Quigley, 1984

Saline Leachate Migration Through Clay: A Comparative Laboratory and Field Investigation. Canadian Geotechnical Journal, vol. 21, pp 349 to 362.

Desaulniers, D.E., J.A. Cherry and P. Fritz, 1981

Origin, Age and Movement of Pore Water in Argillaceous Quaternary Deposits at Four Sites in Southwestern Ontario. Journal of Hydrology, vol. 50, pp 231 to 257.

Desaulniers, D.E., 1986

Groundwater Origin, Geochemistry and Solute Transport in Three Major Glacial Clay Plains of East-Central North America. A thesis presented to the University of Waterloo in fulfillment of the thesis requirement for the degree of Doctor of Philosophy in Earth Sciences, Waterloo, Ontario

Freeze, R.A. and Cherry, J.A., 1979

Ground water. Prentice-Hall Inc. New Jersey, 604 pp.

Gartner Lee Limited, 1987a.

Site Assessment Phase 4B: Geology, Hydrogeology and Geotechnics, Baseline Conditions. Report prepared for the Ontario Waste Management Corporation (Draft).

Gartner Lee Limited, 1987b.

Site Assessment Phase 4B: Geology, Hydrogeology and Geotechnics - Hydrogeologic Input to Landfill Design; Report prepared for the Ontario Waste Management Corporation (Draft).

Gartner Lee Limited, 1987c.

Site Assessment Phase 4B: Geology, Hydrogeology and Geotechnics-Geotechnical Input to Facilities Design. Report prepared for the Ontario Waste Management Corporation.

Gartner Lee Limited, 1987d.

Site Assessment Phase 4B: Geology, Hydrogeology and Geotechnics - Potential Impacts on Ground Water from the Landfill; Report prepared for the Ontario Waste Management Corporation (Draft).

Gartner Lee Limited, 1987e.

Site Assessment Phase 4B: Geology, Hydrogeology and Geotechnics - Ground Water Management Strategies. Impact Management, Monitoring, Contingencies and Facility Decommissioning; Report prepared for the Ontario Waste Management Corporation (Draft).

Heystee, R.J., and H.M. Johnston, 1984.

Hydrogeologic Investigations at two Ontario Hydro Waste Management Facilities; in Proceedings of the International Groundwater Symposium on Groundwater Resources Utilization and Contaminant Hydrogeology, Volume II, International Association of Hydrogeologists, Montreal, Quebec, Canada. pp 413 to 431.

Johnson, R.L., J.A. Cherry and J.F. Pankow, 1986.

Diffusive Contaminant Transport in Natural Clay: A Field Example and Implications for Clay-Lined Waste Disposal Sites, a paper prepared for submission to Environmental Science and Technology, by the Oregon Graduate Center, Beaverton, Oregon and the Institute for Ground Water Research, University of Waterloo, Ontario

M.M. Dillon Ltd., 1987.

Site Assessment - Phase 4B, Surface Water, A draft report prepared for the Ontario Waste Management Corporation, July 1987.

Monenco Limited, 1986a.

OWMC Treatment Facility Process Area Report - General Facilities. A report prepared for the Ontario Waste Management Corporation, November, 1986.

Monenco Limited, 1986b.

OWMC Treatment Facility Process Area Report - Incineration. A report prepared for the Ontario Waste Management Corporation, November, 1986.

Monenco Limited, 1986c.

OWMC Treatment Facility Process Area Report - Physical/Chemical Treatment. A report prepared for the Ontario Waste Management Corporation, November, 1986.

Monenco Limited, 1986d.

OWMC Treatment Facility Process Area Report - Solidification. A report prepared for the Ontario Waste Management Corporation, November, 1986.

Monenco Limited, 1986e.

OWMC Treatment Facility Process Area Report - Engineered Landfill. A report prepared for the Ontario Waste Management Corporation, November, 1986.

Monenco Limited, 1986f.

OWMC Treatment Facility Process Area Report - Facility Description. A report prepared for the Ontario Waste Management Corporation, December, 1986.

Monenco Limited, 1986g.

Site Selection Process Phase 4A: Selection of a Preferred Site(s) - Engineering. A report prepared for the Ontario Waste Management Corporation.

Monenco Limited, 1987.
Design and Operations Report; Report prepared for the Ontario Waste Management Corporation (Draft).

Ontario Ministry of the Environment, 1983.
Ontario Drinking Water Objectives. 56 p.

Ontario Waste Management Corporation, 1982.
Facilities Development Process, Phase 1 Report; September 1982.

Ontario Waste Management Corporation, 1983.
Facilities Development Process, Phase 2 Report; January 1983.

6.0 GLOSSARY

Definitions for selected terms used in this report are provided in this section.

Sources, where applicable, are provided at the rear of this section and are referenced by the bracketed number following each definition.

Some definitions are altered slightly to reflect usage in this report and may not reflect the wide range of meanings provided in the source.

Adsorption

The capture on soil particles of molecular or ionic chemicals dissolved in the ground water by the strong, naturally occurring forces of attraction on the surface of the solid.

Advection

The process by which fluids and constituents dissolved in the fluid are transported by the bulk motion of the flowing ground water (10)

Aquifer

A body of sediment (or rock) that contains sufficient saturated permeable material to conduct ground water and yield economically significant quantities of ground water to wells and springs.

Aquitard

Generally used to describe the less-permeable material in a stratigraphic sequence. This material may be permeable enough to transmit water in quantities that are significant in the study of regional ground water flow, but their permeability is not sufficient to allow the completion of wells for supply within them.

Average Linear Ground Water Velocity (v)

The average rate of ground water movement through saturated rock or soil. The equation for average linear ground water velocity is $v = Ki/n$ where K is the saturated hydraulic conductivity of the geologic material, i is the hydraulic gradient and n is the porosity of the geologic material.

Clay

See Particle Size Classification

Contingency

A plan for protecting the environment which outlines specific responses to unanticipated, but conceivable, events (13)

Decommissioning

The permanent closure of an industrial plant or a waste facility area to an environmentally safe condition consistent with its surroundings and posing minimal risks to human health.

Deuterium (H^2)

This is naturally occurring stable isotope of hydrogen. Stable means it is not radioactive. Deuterium comprises approximately 0.16% of the hydrogen in sea water.

Diffusion

Diffusion in solutions is the process whereby ionic or molecular constituents move under the influence of their kinetic activity in the direction of their concentration gradient. Diffusion can occur in the absence of any bulk hydraulic movement of the solution. If the solution is flowing, diffusion is a mechanism, along with mechanical dispersion, that causes mixing of ionic or molecular constituents. (10)

Dispersion

During flow through porous media, substances dissolved in the ground water (known as solutes), tend to spread out from the path they would be expected to follow based only on the ground water flow path and velocity. This spreading phenomenon is called hydrodynamic dispersion. It causes dilution of the solute. It occurs because of mechanical mixing during flow through the soil pores and because of molecular diffusion. (10)

Dispersivity

A characteristic property of the porous medium in describing the mechanical mixing portion of dispersion (10)

DNAPL (dense non-aqueous phase liquids)
contaminants that are essentially insoluble and are more dense than water.

Dynamic ground water flow

See transient ground water flow

Evapotranspiration

Water losses to the atmosphere through the combined processes of evaporation from open water bodies, evaporation from soil surfaces and transpiration from the soil by plants. (10)

Fracture Porosity

Porosity of which is due to fractures. This is a particular type of secondary porosity (see secondary porosity).

Geotechnical, Geotechnics

Pertaining to the broad field of geotechnics. The application of scientific methods and engineering principles to the acquisition, interpretation, and use of knowledge of materials of the earth's crust for the solution of engineering problems.

Glaciolacustrine

Pertaining to sediments deposited in glacial lakes.

Ground water divide

A point or line in the subsurface across which there is no ground water flow.

Ground water impact

The degradation of ground water quality due to the introduction of pollutants.

Hazardous Waste

Waste that poses a present or potential danger to human beings or other organisms because it is toxic, flammable, radioactive, explosive, or has some other property that produces substantial risk to life. (1) (Use here excludes radioactive waste)

Hydraulic Conductivity

The proportionality factor in Darcy's law as applied to the viscous flow of water in soil, that is, the flux of water per unit gradient of hydraulic potential. (3) [i.e., how easily water moves through the saturated geologic material (note: the lower the hydraulic conductivity the more "resistive" the material is to ground water flow)]

Hydraulic Gradient

The rate of change of total head per unit of distance of flow at a given point and in a given direction. (1) [i.e., the difference in ground water pressures over a lateral or vertical distance]

Hydraulic Head

The height (elevation) to which water rises in a ground water monitor [i.e., a measure of the ground water pressure over the interval (the depth) the monitor is screened].

Hydrogeology

The science that deals with subsurface waters (ground waters) and with related geologic aspects of surface waters. (1)

Hydrostratigraphic Unit

A term proposed by Maxey (1964, p.126) for a body of rock having considerable lateral extent and composing "a geologic framework for a reasonably distinct hydrologic system". (1) (used here for soil and rock).

Infiltration

The entry into the soil of water made available at the ground surface, together with the associated flow away from the ground surface within the unsaturated zone (10)

Intergranular Porosity (also "Primary Porosity")

Porosity which is due to the soil or rock matrix. (10)

Isotope

One of two or more species of the same chemical element; i.e. having the same number of protons in the nucleus, but differing from one another by having a different number of neutrons. The isotopes of an element have slightly different physical and chemical properties, owing to their mass differences, by which they can be separated. (1)

Leachate

Contaminated ground water of a given chemistry due to leaching of constituents from a source area.

Liner

An engineered device which isolates material or fluid from the underlying geologic materials and ground water.

LNAPL (light non-aqueous phase liquids)
contaminants that are essentially insoluble and are less dense than water.

Mitigation

A feature built into the design to minimize impacts from normal and upset operations.

Non-reactive

Pertaining to constituents which do not chemically interact with or alter in the presence of other materials.

Non-aqueous

Pertaining to materials which will not dissolve in water or have a relatively low solubility such that they remain as a separate phase when mixed with water.

Overburden

Unconsolidated material overlying bedrock.

Oxygen-18 (^{18}O)

This is a naturally occurring stable (non-radioactive) isotope of oxygen. Oxygen-18 comprises approximately 0.20% of the oxygen in sea water.

Particle Size Classification System (9)

Name	Qualifying Term	Approximate Particle Size (mm)
Boulders		>200
Cobbles		60 - 200
Gravel	(Pebble)	2 - 60
Sand	Coarse	0.6 - 2
	Medium	0.2 - 0.6
	Fine	0.06 - 0.2
Silt		0.002 - 0.06
Clay		<0.002

Permeability

The capacity of a porous medium to transmit a liquid or gas subjected to an energy gradient (in the case of water, hydraulic gradient). (2)

Piezometer

A pipe or tube in the ground which allows for the determination of water level elevation. It is usually constructed with a slotted pipe or screen at the bottom that permits inflow of water but not geologic materials; it is sealed above the screened section, and it is open to the atmosphere at the top. (10)

Pore Water Pressure

Stress transmitted through pore water. (5)

Porosity

The ratio of the volume of voids to the total volume of a soil sample. (4). Effective porosity is the amount of interconnected space available for fluid transmission (3).

Recharge

The entry into the saturated zone of water made available at the water table surface, together with the associated flow away from the water table within the saturated zone. (10)

Saturated

Said of the condition in which the interstices (pores) of a material are filled with a liquid, usually water. It applies whether the liquid is under greater than or less than atmospheric pressure, so long as all connected interstices are full. (10

Secondary Porosity

Porosity which may be due to such phenomena as secondary chemical solution or fracturing. (10)

Solute

Dissolved ions and molecules in the ground water. (10)

Sorption

See Adsorption

Standpipe

A particular type of piezometer whereby the screened interval straddles the water table elevation.

Static (Water) Level

The water level of a well or monitor when it is not being affected by withdrawal of ground water. (1)

Stratigraphic Unit

A stratum or body of adjacent strata recognized as a unit in the classification of a rock sequence with respect to any of the many characters, properties, or attributes that rocks may possess. (1)

Steady-State ground water flow

Occurs when at any point in a flow field the magnitude and direction of the flow are constant with time (10)

Tank Farm

An area for the temporary storage of materials in tanks

Transient ground water flow

Non-steady state flow

Till

An unsorted mixture of clay, silt, sand, pebbles, cobbles and boulders deposited directly by glacier ice. (2)

Tritium (^3H)

This is a radioactive isotope of hydrogen with a half life of approximately 12.3 years. (10)

Water Budget (Also: water balance, hydrologic budget)

An accounting of the inflow to, outflow from, and storage in a hydrologic unit such as a drainage basin, aquifer, soil zone, lake or reservoir; the relationship between evaporation, precipitation, runoff and the change in water storage, expressed by the hydrologic equation. (1)

Water quality

The chemical composition of water, including trace elements.

Water Table

A surface in the saturated zone below ground level along which the hydrostatic pressure is in equilibrium with the atmospheric pressure. (2)

Weathering

The destructive process or group of processes by which Earthy and rock materials on exposure to atmospheric agents at or near the earth's surface are changed in colour, texture, composition, firmness, or form with little or no transport of the loosened or altered material; specifically, the physical disintegration and chemical decomposition of rock that produce an in-situ mantle of waste and prepare sediments for transportation. (1)

Well Interference

Any action which will impact the availability of water in a well.

SOURCES FOR GLOSSARY

(1) Glossary of Geology (Second Edition); R.L. Bates and J.A. Jackson; American Geological Institute, Falls Church, Virginia, 1980.

(2) Ontario Engineering Geology Terrain Study Users' Manual; J.F. Gartner, J.D. Mollard, and M.A. Roed; Ministry of Natural Resources, 1981.

(3) Permeability and Ground Water Contaminant Transport (A Symposium sponsored by ASTM, Philadelphia, 17-23 June, 1979); ASTM Special Technical Publication 746.

(4) A Dictionary of Civil Engineering, J.S. Scott; Penquin Books, 1985.

(5) Pit Slope Manual, Chapter 5, Design; Minerals Research Program, Mining Research Laboratories, Canmet Report 77-5, 1977.

(6) Fundamentals of Soil Behaviour; J.K. Mitchell; John Wiley and Sons Inc., 1976.

(7) Soil Mechanics in Engineering Practice; K. Terzaghi and R.P. Peck; John Wiley and Sons, 1967.

(8) Canadian Manual of Foundation Engineering; Issued by The Associate Committee on the National Building Code, National Research Council of Canada; 1978.

(9) Bulletin of the International Association of Engineering Geology; (Symposium on Engineering Geological Problems of Construction on Soluble Rocks; Istanbul, Turkey, Sept. 14-18, 1981); Published by the International Association of Engineering Geology.

(10) Groundwater; J.A. Cherry and R.A. Freeze; Prentice Hall Inc., New Jersey, 604 p, 1979.

(11) American Society for Testing and Materials. Annual book of ASTM Standards, Section 4, Construction. volume 04.08. Soil and Rock; Building Stones, 1985.

(12) Physical geology; R.F. Flint and B.J. Skinner; John Wiley and Sons; New York.

(13) Ontario Ministry of the Environment. 1987. Guidelines for the Hydrogeologic Assessment of Proposed Landfills.

APPENDIX A. CENTRAL OPERATING AREA ENGINEERED CONTAINMENT AND OPERATIONAL CONSIDERATIONS

TABLE A-1 CENTRAL OPERATING AREA ENGINEERED CONTAINMENT FEATURES AND OPERATIONAL CONSIDERATIONS

Facility Component	Containment Features and Operational Considerations
Roadways	Primary Containment • separate entrances for vehicles delivering waste and reagents, for those transporting personnel and for emergency vehicles • one way traffic wherever practical • design which minimizes travel distances for fully loaded vehicles • paved roadways Secondary Containment • runoff collected and discharged to potentially contaminated surface drainage system Operations • visual inspection of roadways with prompt repairs of pavement cracks, etc. and spill cleanup
Truck Unloading Areas and Waste Pits	Primary Containment • design includes separate unloading areas for organic and inorganic wastes which can specifically handle liquids/sludges, dry bulk waste and containerized waste • Unloading stations are designed with chemically resistant sloped surfaces and curbs (station sized to contain contents of maximum sized transport vehicle)

(cont'd.)

Facility Component	Containment Features and Operational Considerations
Truck Unloading Areas and Waste Pits	• unloading stations have roofs, sidewalls and end-walls for weather protection • tanks and piping are waste compatible • steel tanks for organic waste and FRP tank for inorganic waste in truck unloading areas. • steel liners for dry organic waste pit at incinerator and solidification plant • heating coils and insulation to prevent freezing of pipes and tank contents Secondary Containment • any below ground tanks will be located in separate concrete pits • each pit drains to its own sump which is equipped with a level alarm • curbs around truck unloading areas to contain spills Operations • visual inspection with prompt repair of cracks and spill clean-up
Storage Tanks, Storage Tank Areas and Pumps	Primary Containment • tank and storage areas designed to comply with applicable regulations and guidelines • dedicated tanks and tank groupings for specific wastes • heating coils to prevent freezing of pipes and tank contents • tanks raised to facilitate inspection and repairs

(cont'd.)

Facility Component	Containment Features and Operational Considerations
Storage Tanks, Storage Tank Areas and pumps	• overflow controls including level alarms (level monitoring system includes feed shut-off valves, overflow piping and overflow collection tanks) Secondary Containment • reinforced concrete floors and dykes in tank farm, dyked areas exceed volume of the largest tank • pumps located in special curbed areas (outside dyke area) that drain to sump • overflow of Phys/Chem dyked areas to potentially contaminated drainage system Operations • liquids (including runoff) tested prior to release • spills cleaned up promptly by portable pumps
Process Area	Primary Containment • integrity of equipment (tanks, pumps, piping controls, alarms, etc) Secondary Containment • concrete and/or tiled floors surrounded by curbs • lined floor drains which discharge into drainage sumps (sump consists of a sump tank in concrete pit) with overflow to potentially contaminated drainage system • sumps have duplex pumps, automatic controls and level alarms

(cont'd.)

Facility Component	Containment Features and Operational Considerations
Ponds	Primary Containment • ponds sized to accommodate peak storm loadings • ponds equipped with discharge controls and level alarms Secondary Containment • double synthetic liners with permeable material between liners to facilitate monitoring and contingency leakage collection Operations • testing of liquids prior to release off-site • replace liner(s) if leak detected

APPENDIX B. POTENTIAL EMISSION SCENARIOS

APPENDIX B. POTENTIAL EMISSION SCENARIOS

Various potential contaminant emission scenarios identified by OWMC staff and engineering consultants are briefly described in this Appendix. Information on the emissions was obtained from the following sources:

- Appendix B.2 of the report "Site Selection Process Phase 4A: Selection of a Preferred Site(s), Engineering" prepared in May 1986 by Monenco Limited for OWMC;
- Memo to Mr. R.V. Griffiths, OWMC, from Mr. I.T. Caines, Monenco dated May 7, 1985, titled "Input to Site Selection Hydrogeology/Landfill - Workshop Input Spill Containment"; and
- discussions with OWMC engineering staff (E.H. Schmidt and C.C. Chao).

The emissions scenarios described below represent the widest possible range of foreseeable "worst case" events which may occur at any time during the life of the facility. No attempt has been made to determine the probability or frequency of occurrence of these events. The summary discussion of each of the events includes a description of the event, identification of the contaminant (waste, additives and/or reagents, organic, inorganic, untreated, treated, undiluted, diluted), likely contaminant pathway, response action and effectiveness of response.

B.1 RECEIVING BASIN RUPTURES

Event: Rupture of a receiving basin during the unloading of a tanker truck releasing contaminants to the below ground pit in which the basin is located.

Contaminant: Organic or inorganic untreated and undiluted waste.

Pathway: Contaminant movement away from the pit is anticipated to be limited because of the likelihood of inward ground water gradients in the immediate vicinity of the pit.

Response Action: Detection should be immediate. Response would involve cleanup of waste and repairs to the receiving basin and pit. Interception and collection of contaminated ground water may be feasible, if required.

Response Effectiveness: The response action is anticipated to be relatively effective, although poor access (leak below receiving basin), would make it impossible to remove contaminated soils adjacent to the basin. Residues may remain in the subsurface until plant decommissioning.

B.2 TRUCK OVERTURNS

Event: Tanker truck overturns releasing its contents to paved and unpaved surfaces.

Contaminant: Any waste, additive or reagent brought to the facility.

Pathway: Contaminant movement would be away from the spill site either through pavement cracks into underlying granular backfill if an on-road spill occurs or through soil if an off-road spill occurs.

Response Action: Detection would be immediate. Response would entail containment and cleanup of spilled contents. Spills over off-road areas may involve excavation of contaminated backfill/soil. Collection of contaminated ground water and surface water could be undertaken, if required.

Response Effectiveness: Effectiveness of the response would vary depending on the location of the spill. Spills in the vicinity of buildings and over paved areas, where contaminants have seeped into granular backfill, are anticipated to be the most difficult to respond to. Residues may remain in the subsurface after cleanup and further response may be warranted during plant decommissioning.

B.3 FAILURE OF "POTENTIALLY CONTAMINATED" SEWER

Event: This event assumes that a storage tank and containment dyke fail coincidentally, releasing the tank's contents to a sewer and that the sewer line also fails.

Contaminants: Any waste, additives or reagents stored at the facility.

Pathway: Contaminant movement would be away from the spill/leak site by means of seepage through soils at the location of the sewer line break and possibly through cracks in the concrete pad below the storage tank (described in scenario B.9) and cracks in the base of the sewer sump (described in scenario B.10).

Response Action: Detection of the storage tank failure should occur immediately. Sewer pipe failure may not be detected immediately, especially if the leak is of a minor nature. Response actions would entail removal of residual contents in the tank, repairs to the tank, containment and cleanup of spilled contents and excavation of contaminated backfill/soil. Collection of contaminated ground water and surface water may be undertaken, if required.

Response Effectiveness: The effectiveness of the response action is likely to vary depending on the location of the spill/leak. Seepage of contaminants into granular backfill materials below the tank pad and along foundations will be difficult to respond to. Residues may remain in the subsurface after cleanup and further response may be warranted during plant decommissioning.

B.4 FAILURE OF POND CONTAINING LIQUIDS

Event: This event assumes that both the primary and secondary liners of the retention pond(s) fail releasing contaminated liquids.

Contaminant: Diluted wastes, additives and reagents that have been collected via the facilities contaminated drainage system and possibly leachate collected from the landfill.

Pathway: Contaminant movement from the pond would be dependent on both the liquid level in the pond and the level of the ground water in the soil surrounding the pond. If the ground water level is higher than the liquid level within the pond, hydraulic gradients will be towards the pond and contaminant movement limited. If the reverse occurs, gradients will be away from the pond resulting in the dispersal of contaminants in the subsurface.

Response Action: Detection would depend on the volume of contaminant leaked, location of ground water monitors and monitoring frequency. Response actions would include removal of the remaining pond liquids and repairing the liners, installation of shallow ground water collection wells and drains to intercept and collect contaminants and possibly removal of contaminated backfill/soil.

Response Effectiveness: The effectiveness of the response would vary depending on the volume of waste release and the purging capabilities of collection wells and drains. Residues may remain in the subsurface after cleanup and further response may be warranted during plant decommissioning.

B.5 FAILURE OF DRY BULK UNLOADING PIT

Event: This event assumes that dry waste, stored in below ground unloading pits approximately 8 m deep, becomes wet producing a leachate. The leachate seeps out through cracks in the base and sides of the pit.

Contaminant: Leachate produced from contact of liquid with dry solid waste (organic and/or inorganic).

Pathway: Contaminant movement away from the area of leak would be limited because hydraulic gradients in the vicinity of the pit would likely be towards the pit.

Response Action: Detection would depend on the location of shallow ground water monitors and monitoring frequency. Response actions would include removing the

waste from the pit(s) and repairs to the pit lining. Ground water collection wells could be installed in the general vicinity of the building housing the pit(s) to intercept the leachate, if required.

Response Effectiveness: The response action is anticipated to be relatively effective, although poor access (leak below incinerator and/or solidification buildings), would make it impossible to remove contaminated soils adjacent to the pit. Interception and collection of contaminated ground water may be feasible. Residues may remain in the subsurface following cleanup and further response action may be warranted during plant decommissioning.

B.6 PIPE RUPTURE OR PIPE CONNECTION

Event: This event assumes that a pipe location on an above ground pipe rack ruptures or a pipe connection leaks or breaks, resulting in the release of waste, additive or reagent onto paved and/or unpaved surfaces.

Contaminant: Any waste, additive or reagent transferred through the piping system.

Pathway: Contaminant movement would be away from the area of the spill/leak through pavement cracks (described in scenario B.9), along foundations or directly into backfill/soil.

Response Action: Major leaks should be detected immediately by process monitoring. Minor leaks may not be detected immediately resulting in the slow release of contaminants over an extended period of time. Response actions would include repairing the pipe or connection, containment and cleanup of the spilled material and excavation of contaminated backfill/soil. Collection of contaminated ground water and surface water could be undertaken, if required.

Response Effectiveness: Effectiveness of the response action would be dependent on the location of the spill/leak. Spills adjacent to buildings and seeps through the pavement cracks resulting in contaminant movement along foundations and through

backfill would be the most difficult to respond to. Residues may remain in the subsurface after cleanup and further response action may be warranted during plant decommissioning.

B.7 FAILURE OF STORAGE TANK

Event: Two events are assumed: (a) that a storage tank ruptures, the dyke containment wall collapses and the tank's full contents are released; and (b) that a small leak occurs in a tank.

Contaminant: Any waste, additive or reagent stored in tanks at the facility.

Pathway: Contaminant movement would be away from the area of the spill/leak either directly through backfill/soil or indirectly through pavement cracks (described in scenario B.9) or potentially the failure of the contaminated sewer or sump (described in scenario B.3 and B.10, respectively).

Response Action: Detection of tank rupture should be immediate. A minor leak may not be detected immediately resulting in a small loss of contents over an extended period of time. Response actions would include removal of the residual contents of the tank, containment and cleanup of spilled materials. Excavation of contaminated backfill/soil and collection of contaminated ground water and surface water could be undertaken, if required.

Response Effectiveness: Effectiveness of the response action would vary depending on the location of the spill/leak. Spill seepage through pavement cracks and the resulting contamination of underlying granular backfill, would be the most difficult to respond to. Residues may remain in the subsurface after cleanup and further response action may be warranted during plant decommissioning.

B.8 LEAKAGE AT PUMP SEAL AND/OR PIPE JOINT

Event: This event assumes that leakage occurs at pump seals or pipe joints and that contaminants are spilled on paved and/or unpaved surfaces.

Contaminant: Any waste, additive or reagent which is pumped at the facility.

Pathway: Contaminant movement would be away from the area of the spill/leak either directly through backfill/soil or indirectly through pavement cracks or potentially, the failure of the contaminated sewer (described in scenario B.3) or floor sump (described in scenario B.10).

Response Action: Minor leaks may not be detected immediately resulting in a small release of contaminants over a prolonged period of time. Response actions would include repairs to the seals or pipe joints, and containment and cleanup of the contaminants.

Response Effectiveness: Effectiveness of the response action would vary depending on the location of the spill/leak. Spill seepage through pavement cracks, and the resulting contamination of underlying granular backfill, would be the most difficult to respond to. Residues may remain in the subsurface after cleanup and further response action may be warranted during plant decommissioning.

B.9 LEAKS THROUGH FLOOR SLAB OR ROADWAY

Event: This event assumes the seepage of small volumes of spilled contaminants through cracks in floor slabs and other paved surfaces.

Contaminant: Any waste, additive or reagent handled at the facility.

Pathway: Seepage of contaminants through pavement cracks and movement through subpavement granular backfill materials.

Response Action: Elapsed time before detection would vary depending on the volume of contaminant released, location of ground water monitors and monitoring frequency. Response actions may include excavation of contaminated backfill/soil and the collection of contaminated ground water and surface water.

Response Effectiveness: Effectiveness of the response action would vary depending on the location of the spill/leak. Spill seepage through pavement cracks, and the resulting contamination of underlying granular backfill, would be the most difficult to respond to. Residues may remain in the subsurface after cleanup and further response action may be warranted during plant decommissioning.

B.10 FAILURE OF FLOOR DRAIN SUMP PUMP

Event: This event assumes that a pump located in a floor drain sump fails, the alarm malfunctions and the sump leaks into the surrounding backfill/soil.

Contaminant: Any waste, additive or reagent handled at the facility.

Pathway: Contaminant movement would be through cracks in the base and sides of the sump into granular backfill and/or soil.

Response Action: Detection would occur either visually because the sump fills faster than it leaks, during routine maintenance or as a result of ground water monitoring. Response actions would include removal of contaminated liquids in the sump and repairs to the sump, pump and alarm. Collection of contaminated ground water may be feasible by purging of the sump during high water table conditions.

Response Effectiveness: Effectiveness of the response would vary depending on the location of the sump. Contamination of backfill/soil below buildings would be difficult to respond to. Residues may remain in the subsurface after cleanup and further response action may be warranted during plant decommissioning.

APPENDIX C. MODEL DOCUMENTATION

SOFTWARE FACT SHEET

SOFTWARE NAME: "PATSOURCE"

AUTHORS : R. McLaren and S. Hollingshead (Gartner Lee Ltd.)

COMPUTER SYSTEM/LANGUAGE : HP9816/BASIC 2.0

DESCRIPTION:

PATSOURCE is a three-dimensional, analytical solution to the advection/dispersion equation that describes the transport of contaminants in ground water. The source of the contaminants will be a rectangular patch (area) of any size, and the contaminant source can exist indefinitely or for a finite length of time.

The model can account for chemical attenuation processes such as sorption and first order decay (hydrolysis or radioactive decay, for instance) if the appropriate attenuation parameters are specified.

PATSOURCE provides profiles of relative concentration versus either time or distance and has a built-in plotting function to give an accurate graphical representation of the results.

APPLICATIONS:

Application of solute transport models are important in contaminant hydrogeological assessments. The PATSOURCE model can be used to predict the nature of a contaminant plume, or to model the behavior of an existing plume by matching results with field data. The source input is very flexible; it can range from a small hole in a subsurface pipe up to an entire landfill. By including attenuation and a finite duration source, realistic field situations can be better simulated.

ASSUMPTIONS:

- steady state ground water flow through a fully saturated porous medium which is homogeneous and isotropic with respect to material properties
- contaminant transport governed by the advection/dispersion equation
- semi-infinite transport medium
- constant or variable contaminant release rate during active life of source

INPUT PARAMETERS:

- source type:
  - (1) continuous release source
  - (2) finite duration source including source life
  - (3) cyclic loading of source over active life
  - (4) variable loading rate over active life
- source dimensions
- choice of attenuation processes:
  - (1) no attenuation
  - (2) (a) distribution coefficient for chemical species, and porosity and bulk density of porous medium for sorption calculation
    - (b) chemical species halflife for first order decay calculation
- average linear ground water velocity
- dispersion coefficient, or coefficient of molecular diffusion and dispersivity, in each coordinate direction
- time and location information for each calculation
- number of numerical integration points required

OUTPUT:

- profiles of relative concentration versus:
  - (1) time at a specified distance, or
  - (2) distance at a specified time
- data table printout and/or data plots

SET-UP TIME: less than five minutes.

RUN TIME:

Less than five minutes to several hours per run, depending on the complexity of the problem and the accuracy required. Continuous supervision is not required for longer runs.

SOFTWARE FACT SHEET

SOFTWARE NAME: "BLOKSOURCE"

AUTHORS : R. McLaren and S. Hollingshead (Gartner Lee Associates Ltd.)

COMPUTER SYSTEM/LANGUAGE : HP9816/BASIC 2.0

DESCRIPTION:

BLOKSOURCE is a three-dimensional, analytical solution to the advection/dispersion equation that describes the transport of solutes in ground water. It models the migration of an instantaneously released, block-shaped source.

The model can account for chemical attenuation processes such as sorption and first order decay (hydrolysis or radioactive decay, for instance) if the appropriate attenuation parameters are specified.

BLOKSOURCE provides profiles of relative concentration versus either time or distance and has a built-in plotting function to give an accurate graphical representation of the results.

APPLICATIONS:
Two types of solutes common in ground water studies are contaminants and tracers. The BLOKSOURCE model can be used to predict the nature of a contaminant plume, or to model the behavior of an existing plume by matching results with field data. Contaminant sources of the type simulated by the BLOKSOURCE model could include spills or short-duration leaks.

BLOKSOURCE can also be used to simulate the transport of tracers, either in field or laboratory situations. This can be a valuable method of verifying test results or performing rapid, economical sensitivity studies.

The distribution of either solute type can be represented by concentration contour maps or cross sections at selected times by repeated runs of the BLOKSOURCE model.

ASSUMPTIONS:
- steady state ground water flow through a fully saturated porous medium which is homogeneous and isotropic with respect to material properties
- contaminant transport governed by the advection/dispersion equation
- semi-infinite transport medium
- solute is released as an instantaneous slug with regular block-shaped dimensions

INPUT PARAMETERS :

- initial source dimensions
- choice of attenuation processes:
  (1) no attenuation
  (2) (a) distribution coefficient for chemical species, and porosity and bulk density of porous medium for sorption calculation
      (b) chemical species halflife for first order decay calculation
- average linear ground water velocity
- dispersion coefficient, or coefficient of molecular diffusion and dispersivity, in each coordinate direction
- time and location information for each calculation

OUTPUT :
- profiles of relative concentration versus:
  (1) time at a specified distance, or
  (2) distance at a specified time
- data table printout and/or data plots

SET-UP TIME : less than 5 minutes.

RUN TIME : typically 5 to 15 minutes.

REFERENCE:
Sudicky, E.A., J.A. Cherry, E.O. Frind, 1983. Migration of contaminants in groundwater at a landfill: a case study, 4. a natural-gradient dispersion test. Journal of Hydrology, 63, pp. 81-108.

APPENDIX D. CONSTITUENTS OF SPECIAL WASTE

CONSTITUENTS OF SPECIAL WASTE

UCD WASTE	DESCRIPTION	TYPICAL WASTES	Estimated Waste Quantity (tonnes)
11 ACIDIC SOLUTIONS			
111	Acidic Solution with Heavy Metals	Pickle Liquor Rinse Water	149,000
112	Acidic Solution with Other Metals and Non-Metals	Demineralizer Regenerent	800
113	Other Acidic Solutions	Boiler Stack Scrubber Water with Dilute Carbonic Acid (H_2CO_3)	22,600
12 ALKALINE SOLUTIONS			
121	Alkaline Solution with Heavy Metals	Rinse Waters from Surface Cleaning of Metals	19,500
122	Alakaline Solution with Other Metals	Demineralizer regenerent	700
123	Other Alkaline Solutions	Cleanup Water from Lime or Cement Kiln	55,200
13 METAL FINISHING SOLUTIONS			
131	Metal Finishing Solutions, Acid	Ammonia Based, Containing Copper, Tin, Lead or Cadmium	9,900
132	Metal Finishing Solutions, Alkaline	Contains Strong Complexing Agent and Copper, Tin, Lead and/or Cadmium	1,100
133	Spend Pickle Liquor from Ferrous and Non Ferrous Metals	Strong Acids with Iron, Fluoride, Hydrochloric Acid (HCl), Sulfuric Acid (H_2SO_4), Nitric Acid (HNO_3)	213,400

CONSTITUENTS OF SPECIAL WASTE

UCD WASTE	DESCRIPTION	TYPICAL WASTES	Estimated Waste Quantity (tonnes)
14 OTHER AQUEOUS SOLUTIONS			
141	Aqueous Solutions with Heavy Metals	Cleaning Solutions from Tanks, Trucks, or Railroad Tankers	32,300
142	Aqueous Solutions with Other Metals	Rinse Water from Heat Treating Salt Baths, Contain Barium, Aluminum	200
143	Aqueous Solutions with Reactive Anions	Bleaching Solutions Containing Sulfite, Chlorite, Fluoride, Bromate	2,900
145	Brine	Salt Solutions After Neutralization or Chlor/Alkali Production	5,400
146	Solutions Containing Cyanide	Plating Baths	4,800
147	Solutions Containing Sulfides	Plating Baths	2,600
15 INORGANIC SOLIDS			
151	Inorganic Solids	Foundry Sand with Phenolics	133,000
152	Inorganic Solid Chemicals	Aged or Off Spec. Chemicals Including Lime, Caustic Soda and Partial Containers of Laboratory Size	132,100
16 OTHER INORGANIC WASTES			
165	Spent Catalyst	Maybe Carbon or Metal	2,000
167	Other Inorganic Waste	Ash and Construction Residue	1,700

CONSTITUENTS OF SPECIAL WASTE

UCD WASTE	DESCRIPTION	TYPICAL WASTES	Estimated Waste Quantity (tonnes)
21 SPENT SOLVENTS			
211	Halogenated Solvents with Heavy Metals	Methylene Chloride, 1, 1, 1, Trichloroethylene Used for Metal Cleaning	3,700
212	Halogenated Solvents with Other Metals	Surface Cleaning and Degreasing Solvents	< 100
213	Other Halogenated Solvents	Freon with Other Solvents Used in Chemical Processing	2,000
214	Non-Halogenated Solvents with Heavy Metals	Toluene, Benzene, Xylene Contaminated with Catalysts	17,500
215	Non-Halogenated Solvents with Other Metals	Acetone, Methylisobutylketone (MIBK) used in Paint and Varnish Formulation	300
216	Other Non-Halogenated Solvents	Methylethylketone and Other Solvents Contaminated with Dirt	4,700
217	Unspecified Solvents	Alcohols and Mixtures of Solvents	700
22 OTHER ORGANIC LIQUIDS			
221	Organic Liquids with Metals and Halogens	Dyes	< 100
222	Organic Liquids with Halogens Only	Chloroform, Carbon Tetrachloride	900
223	Organic Liquids with Metals Only	Nickelcarbonyl, Methyl Mercury	200
224	Other Organic Liquids	Creosote and Other Poly Aromatic Hydrocarbons	12,200
225	Aqueous Solution with Non-Halogenated Residues Less Than 10%	Laboratory Mixtures	3,100
226	Aqueous Solutions with Halogenated Residues Less Than 10%	Waste or Rinse Waters After Degreasing	1,000

CONSTITUENTS OF SPECIAL WASTE

UCD WASTE	DESCRIPTION	TYPICAL WASTES	Estimated Waste Quantity (tonnes)
227	Aqueous Solution with Non-Halogenated Organic Residue Greater Than 10%	Laboratory Mixtures	200
228	Aqueous Solution with Halogenated Organic Residue Greater Than 10%	Wash or Rinse Waters after Degreasing	100
24 - 25 OTHER ORGANIC WASTES			
241	Pesticides and Wastes	Partial Containers, Tank Washings, Off Spec. Product, etc.	600
242	PCB Oils and High Strength (over 500 ppm) Liquids	From Transformers and Capacitors	200
243	Pharmaceuticals and Wastes	Off-Spec. Drugs, Cleanup Waters, etc. Includes Items such as Vitamins	1,700
244	Photochemical Waste	Most Solutions Non-Toxic Except those with Silver	5,000
245	Off-Spec or Aged Organics	Can Include Solids or Liquids. Generally in Containers	200
247	Halogenated Still Bottoms	Spent Solvent or Waste Oil Recovery	2,500
248	Non-Halogenated Still Bottoms	Solvent Recovery Operations	7,500
251	Tannery Wastes - Liquid	Solutions with Hexavalent Chromium.	1,900
252	Solid or Sludge Tannery Wastes	Leather Shavings with Chrome,	1,000
254	Adhesives or Glue	Waste Glues Mostly Aqueous. Some with Phenols	< 100

CONSTITUENTS OF SPECIAL WASTE

NCD WASTE	DESCRIPTION	TYPICAL WASTES	Estimated Waste Quantity (tonnes)
257	Phenolic Wastes	Phenolic Oil. Toluene Diisocyanide Residue	1,900
258	Waste Tar and Residues		900
26 POLYMERIC MATERIAL WASTES			
261	Polymeric Resin	Polyester, Urethane, Etc.	1,400
262	Latex Wastes	Cleanup Water, Paint, Latex and Acrylic Resins	9,600
263	Other Polymeric Wastes	Kettle Bottoms, Thermoplastic Resins,	1,400
264	Thermoset Wastes	Urea-Formaldehyde and Thermoset Wastes	1,400
28 OILY WASTES			
281	Waste Oil and Mixed Oil	Used Automotive Oil, Hydraulic Oil, Cutting Oil - May Contain Solvents or Metals	46,600
282	Oily Tank Bottoms	Crude Oil or Sludge from Storage	29,800
283	Oily Mud, Sediment and Water	Crude Oil Tanker Cleaning	69,000
284	Oily Acidic Solids	Solids from Emulsion Breaking and Re-Refining	10,400
285	Oily Alkaline Solids	Refining Solids	6,900
286	Oil/Water Separator Sludge	Oil Cooled Heavy Inorganics	5,000
288	Oily Wastes with Heavy Metal Contaminants	Steel Rolling Mill Sludges and Mill Scale	169,200
289	Oily Wastes with Water	Emulsions, Cleanup Water from Garages, Cooling Waters	100

CONSTITUENTS OF SPECIAL WASTE

UCD WASTE	DESCRIPTION	TYPICAL WASTES	Estimated Waste Quantity (tonnes)
41 RELATIVELY INERT SLUDGES			
416	Ink Sludge	Sludge Could Contain Solvents, and Lead, Cesium, Chromium	4,100
417	Alum and Gypsum Sludges	Waste Water Phosphate. Removal Sludge	1,100
43 METAL SLUDGES			
431	Heavy Metal Sludge	Similar to that in 111, 113, 121, 123, 132, 133, 141,	43,800
433	Other Metal Sludges	Ferric Chloride, Aluminum Oxide, etc.	9,200
44 - 45 OTHER SLUDGES			
441	Lime Sludges	From Treatment of Acids and Similar to 431 and Derived from 111, 113, 121, 123, 131, 132, 133, 141	51,700
443	Sulfur Sludge	Desulfurization of Flue Gas Non-reactive but Very Low Bearing Strength	1,500
444	Cyanide Bearing Sludge	Pot Liners from Aluminum Reduction and Scrubber Sludge from Blast Furnace	27,400
445	Plating or Metal Finishing Sludge	Derived Mostly from 131, 132, 133	6,600
446	Degreasing Sludge	Grease and Oily Soil Containing Trichloroethane (TCE)	28,500
447	Tetraethyl Lead Sludge	Tank Bottoms	< 100
454	Paint Sludge	Drum Bottoms, Spills, Cleanup, etc.	30,600
455	Paint Sludge Without Heavy Metals	Mostly Latexc,	7,600

CONSTITUENTS OF SPECIAL WASTE

UCD WASTE	DESCRIPTION	TYPICAL WASTES	Estimated Waste Quantity (tonnes)
50 - 53 MISCELLANEOUS			
509	Gas Cylinders or Containers	Oxygen Cylinders - Empty	100
512	Spill Cleanup	Oil/Soil Mixture	3,100
513	Laboratory Waste Chemicals	Partially Full Small Containers	1,200
518	Dust Collector Wastes	Dry Lime from Dust Control Baghouse	55,500
521	Spent Cartridge Filters	Air Cleaning Filters on Ventilation System	100
523	Tank Bottom Sediments		3,500
528	Pathogenic Wastes	Used Bandages, Dressings	2,000
531	Contaminated Rags	Cleanup Materials	300
532	Equipment and/or Containers Contaminated with Pesticides	Empty Pesticide Cans	1,800
			1,490,300